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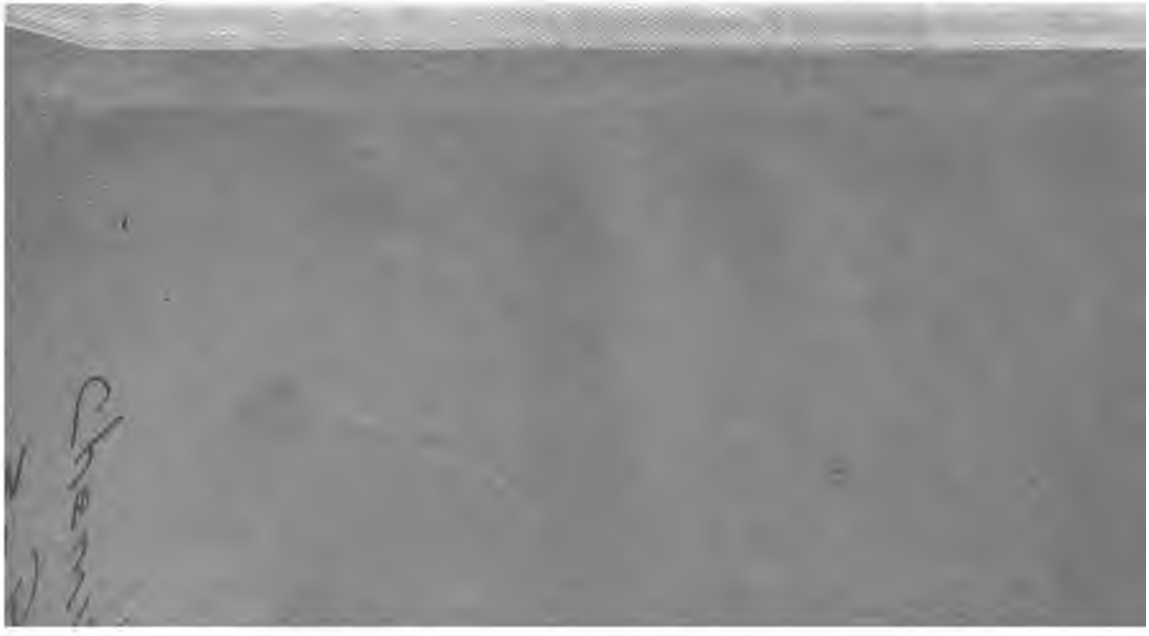

NATURAL PHILOSOPHY

FOR

THE USE OF SCHOOLS.

VOL. III.

CHEMISTRY, AND CHEMICAL ANALYSIS.

CHEMISTRY,

AND

CHEMICAL ANALYSIS,

WITH 33 WOODCUT ILLUSTRATIONS.

FORMING THE THIRD VOLUME OF NATURAL PHILOSOPHY FOR THE USE OF SCHOOLS.

PRINTED AND PUBLISHED BY DIRECTION OF THE

COMMISSIONERS OF NATIONAL EDUCATION IRELAND.

DUBLIN:

ALEX. THOM & SONS, PRINTERS AND PUBLISHERS,

87 & 88, ABBEY-STREET.

LONGMAN, GREEN, & CO., AND GROOMBRIDGE & SONS, LONDON.

FRASER & CO. EDINBURGH.

MDCCCLXI.

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159872
ASTOR, LENOX AND TILDEN FOUNDATIONS.
1899.

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NATURAL PHILOSOPHY.

INORGANIC CHEMISTRY.

CHAPTER I.

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1. NATURE, HISTORY, AND DIVISION OF THE SUBJECT. —Chemistry* is a science, which teaches us the nature of those elements, that constitute all the substances, with which we are acquainted; the mode of their combination; and the properties of the resulting compounds.

2. It is one of the sciences, which are entirely of modern creation. In the earliest times, arts were practised, and processes were employed, which, indeed, are strictly chemical; but which, nevertheless, do not necessarily suppose any acquaintance with chemical science. They were not accompanied with a collection of, and a reasoning from, facts and experiments: nor did they imply any cognizance of its laws, or principles. Chemistry was alike unknown to the sages of Egypt, and to the philosophers of Greece. It even sprung, originally, from delusion, and folly;—since its first and, for a long period, its only object was the production of gold and silver, and the discovery of a "universal remedy" by which every disease might be cured.

* *Fourcroi* gives no less than seven derivations of this word, but does not consider any of them as even plausible.

3. The earliest mention of chemistry, in any boo
tant, is to be found in the dictionary of Suidas, a
writer of, it is probable, the eleventh century, und
word *chemia*. He describes it to be the preparati
gold and silver. There is some reason to believe t
was known to the Greeks, in that sense, so early
fifth century.

4. A knowledge of chemistry—or, as it was first
alchymy—passed, about the ninth century, from the G
to the Arabians, who began, at that period, to pay
attention to the preparation of medicines. It was
duced by the Arabians into Spain; and, finally,
through every part of Europe, causing an infatuation
lasted, with little diminution, for many centuries
which—notwithstanding the denunciations of the wis
the penalties inflicted on its votaries, by kings and p
—carried away enormous multitudes: nor did it
until, being gradually dissipated by the progress of
ledge, it finally disappeared in the seventeenth centu

5. The alchymists, imagined that all metals are
posed of the same ingredients: and that the baser
from gold and silver, only by being contaminated
impurities, which might be removed. They denomi
the substance which was expected to produce this
"The philosopher's stone," "the magistery," &c.
many of them believed, or affected to believe, that
had discovered, or were in possession of it. The de
tions which have come down to us, of the mode of p
ing it, are, for the most part, a mere jargon, that c
be understood: and was not, perhaps, ever intended
so. Lives were wasted, and fortunes dissipated, i
vain attempt to obtain it: and, so great was the de
which prevailed, that those who could not procure as
gold and silver, as would relieve their necessities
eeded in persuading the credulous, that they were
part, for a reward, the mode of obtaining the
and, to keep up the deception, they h
ous expedients, which their dupes
detect.

of the alchymists w
their objects,

undesignedly, greater benefactors to mankind, than if they had succeeded beyond their utmost hopes. Their researches ultimately led to the discovery of one of the noblest, and most generally useful of sciences—one that is, in some way or another, connected with every art and manufacture, whether intended to fabricate the necessaries, the comforts, or the luxuries of life. The alchymists discovered a vast number of the most important substances; and invented most of the processes, and apparatus, that are still used in chemistry.

Since the middle of the seventeenth century, the progress of this science has been most rapid; but it may almost be said to have reached its present state of perfection, within the last century.

7. Chemistry is divided into *inorganic*—or that which treats of simple bodies, with their more immediate, and less complicated compounds; and *organic*, which treats of those combinations, that belong to substances, having organs of increase, repair, and reproduction—that is, which are derived from the animal, or vegetable kingdom. Some compounds, however, such as oxalic acid, which, on account of their simplicity, are conveniently treated of in inorganic chemistry, are found among organic substances.

8. Divisibility of Matter.—It is usual, at the commencement of chemistry, to inquire if matter is infinitely divisible, or not. The dispute on this point is very ancient; but the reasoning, adduced in favour of infinite divisibility, merely shows either that the "space" occupied by matter, can be divided *ad infinitum;* or that the Creator, had he so willed it, could, without any contradiction in terms, have made it divisible without limit.

9. Many arguments, on the other hand, seem to place it beyond a doubt, that matter is, in point of fact, divisible only within certain limits. Thus, the doctrine of *atomic** *weight*, actually teaches us the "relative" weights of the atoms, belonging to the various elements. For, it is found, that only a certain quantity of one element, will unite with a given quantity of another; and that, if we exceed either of these quantities, the excess will be mechanically mixed, *but not* chemically united with the rest. Hence, we must

* *A*, a privative particle; and temno, I cut. Gr.

conclude that, in a given quantity of any element, t
are a certain number of atoms, which can unite w
given quantity of another, only because the numbe
atoms in that other is equal to, or is a multiple, or
multiple of the number of atoms of the former: so th
we exceed the proper weight of either substance, we
atoms, for which there are no corresponding atoms i
other. It follows from this, that we can ascertain
equivalents or relative weights of atoms, though fa
minute to be perceived, even with the aid of the m
scope. In a compound which contains an atom of eac
the elements composing it—water for instance—the s
est particle will have the same proportion, by weigh
each element, as the largest possible quantity. Hen
single particle of water will contain, by weight,
times as much oxygen as hydrogen; and, by consequ
an atom of oxygen, will be eight times as heavy a
atom of hydrogen—provided the water really consis
but one atom of each element.

10. Dr. Wollaston lays it down as a proposition, ap
ently incontrovertible, that, if the gases were infin
divisible, they must, from their elasticity—on accou
the then infinite source of repulsion, the number of r
ling particles being infinite—extend through infinite sp
each planet would have an atmosphere, the densit
which would depend on its size; and all the atmosph
would be of the same kind. But this, certainly, is no
case. It is true, that some of the planets might have
an atmosphere, without our being able to ascertai
existence: since that of the moon, for example, woul
—from her smaller bulk—only as dense as ours, at
distance of 5,000 miles from the earth. Our inquiry n
therefore, be directed to a much larger body. This
not be the sun, since we are not able to say what at
pheric change would be produced by its, probably,
vated temperature. Jupiter presents no such difficu
yet our observations on that planet do not favour
opinion that the atmosphere is infinitely diffused. F
it had the atmosphere that in such supposition it
have, its fourth satellite, when behind its centre
on account of refraction [opt. 9], be visible at ea

it:—which does not occur. However, the argument derived from this source is not, it must be admitted, very conclusive.

11. The doctrine of the non-divisibility of matter beyond a certain limit, was taught by Epicurus and Lucretius. Newton remarks that water, composed of broken, could not be the same, as that which consists of entire particles.

12. But, though matter is not infinitely divisible, it is capable of being divided to an amazing extent. This is proved, by the small quantities of matter required to affect the senses of taste, and smell: the former, is affected only by soluble, and the latter, only by volatile bodies. Also, platinum wire has been drawn, by Wollaston, for astronomical purposes, so fine, that it may be easily proved not to have exceeded the 18,000th part of an inch, in diameter. To obtain it, he surrounded the platinum with silver; then drew the compound wire; and afterwards dissolved away the silver, with nitric acid. A single grain of ammoniacal hyposulphite of silver, will render 32,000 grains of water intensely sweet. A grain of iodide of potassium, dissolved in 480,000 grains of water, and mixed with a little starch, will, on adding some chlorine water, render the entire fluid blue. The black spot on a soap bubble, before it bursts, is only the 2,500,000th part of an inch in thickness. Gold, on silver wire, may be visible to the naked eye, although only the 864,000,000th part of an inch; and, with the microscope, if only the 432,000,000,000th part. Professor Ehrenberg has shown, that there are, in fluids, such vast numbers of minute animals, that a single drop may contain 500,000,000—a number more than half as great, as that of all the human beings on the earth; and yet, each of these creatures is furnished with organs of motion, &c. If the globules in the blood of minute animals, bear the same proportion to the size of their bodies, as the globules of our blood bear to ours, how inconceivably small must they be. For 890,000 red globules of the human blood are required to cover a superficial inch: and* 25,000,000 when deprived of their colouring matter.

13. THE ELEMENTS; WITH THEIR EQUIVALENTS, AND SYMBOLS.—The ancients are supposed, by many, to have

* Phil. Trans.

considered earth, air, fire, and water, as the elementary substances of which all bodies are composed. But, the most enlightened of them, seem to have looked upon these merely as examples of the four different states, which modern science teaches us really belong to matter—the solid, the fluid, the gaseous, and the ethereal. For, Plato, in Timeus, says, "Let us, therefore, speculate concerning the nature and properties of fire and water, air and earth. This is the more arduous, because it is necessary to call into question, concerning each and all of them, whether they should be denominated liquid rather than ethereal, or aerial rather than solid; or why any thing should have one of these appellations, rather than all. For, in the first place, that which we now call water, being congealed, becomes as stone or earth; but being melted or diffused, it becomes gas or air; and this, inflamed, becomes fire; and fire extinct, becomes again congregated into air; and air, collected and condensed, forms mist and cloud; and these again, more compressed, form water; and from the water, earth and stones are reproduced. And thus they, in an endless circuit, produce each other. Since, then, these now appear to be the same, who will assert that one of them is of the one kind, rather than of the other. It is most safe, therefore, to speak thus:—that the thing we see is not absolute liquid, but something in the liquid state; that air is not necessarily a gas, but something in the gaseous state; not as being a particular thing, of this or that specific nature; but that it is in such and such condition. Let us then distribute the four modifications of matter into fire, earth, water, and air; and to earth let us assign an entical form, for it is the most immovable of all; to water, that which is less movable than the other three; to fire, the most easily movable form; and to air, that which is intermediate."

14. However various the bodies which constitute the globe, the elements to which they may ultimately be reduced, are extremely few. These have been variously divided. By Thompson, into *supporters* of combustion, and *non-supporters*. But, when, for instance, water is *produced* by the combustion of hydrogen, the hydrogen *may, with* equal truth, be said to burn the oxygen, as to be *burned by it*. And the same body,—sulphur, for examp

—may be at one time a supporter, and a combustible at another. Berzelius divides them into *electro-negative*, and *electro-positive*—according to that pole of the battery [gal. 60] to which they go. But, as we have remarked [gal. 61] the same substance may be electro-positive with one body, and electro-negative, with another. For convenience, we shall divide them into metals, supporters of combustion, and combustibles—indicated by *met.*, *sup.*, and *comb.* They are, at present, sixty-three in number. With their symbols —generally derived from the first one, or two, letters of their names—and their equivalents or atomic weights [9], so far as the latter have yet been ascertained, they are, according to the best authorities, as follows:—

Name.	Symbol.		Equivalent.
Aluminum,	Al.	*Met.*	13·63
Antimony,	Sb.	*Met.*	129·20
Arsenic,	As.	*Met.*	74·92
Barium,	Ba.	*Met.*	68·39
Bismuth,	Bi.	*Met.*	70·95
Boron,	B.	*Comb.*	10·90
Bromine,	Br.	*Sup.*	79·97
Cadmium,	Cd.	*Met.*	55·74
Calcium,	Ca.	*Met.*	20·00
Carbon,	C.	*Comb.*	6·00
Cerium,	Ce.	*Met.*	46·05
Chlorine,	Cl.	*Sup.*	35·47
Chromium,	Cr.	*Met.*	27·99
Cobalt,	Co.	*Met.*	29·48
Columbium,	Ta.	*Met.*	184·90
Copper,	Cu.	*Met.*	31·68
Didimium,	D.	*Met.*	—
Donarium,	Do.	*Met.*	—
Erbium,	Er.	*Met.*	—
Fluorine,	F.	*Sup.*	18·86
Glucinum,	G.	*Met.*	26·54
Gold,	Au.	*Met.*	98·33
Hydrogen,	H.	*Comb.*	1·00
Ilmenium,	Il.	*Met.*	—
Iodine,	I.	*Sup.*	126·85
Iridium,	Ir.	*Met.*	98·84
Iron,	Fe.	*Met.*	28·00
Lanthanum,	La.	*Met.*	48·00
Lead,	Pb.	*Met.*	103·73
Lithium,	L.	Met.	6·55
Magnesium,	Mg.	Met.	12.02
Manganese,	Mn.	Met.	27·56
Mercury,	Hg.	Met.	100·07

Name.	Symbol.		Equivalent.
Molybdenum,	Mb.	*Met.*	47·96
Nickel,	Ni.	*Met.*	29·53
Niobium,	Nb.	*Met.*	—
Nitrogen,	N.	*Comb.*	14·02
Osmium,	Os.	*Met.*	99·72
Oxygen,	O.	*Sup.*	8·00
Palladium,	Pd.	*Met.*	53·00
Pelopium,	Pe.	*Met.*	—
Phosphorus,	P.	*Comb.*	31·32
Platinum,	Pl.	*Met.*	98·84
Potassium,	K.	*Met.*	39·12
Rhodium,	R.	*Met.*	52·20
Ruthenium,	Ru.	*Met.*	52·10
Selenium,	Se.	*Comb.*	39·63
Silicon,	Si.	*Comb.*	21·35
Silver,	Ag.	*Met.*	107·92
Sodium,	Na.	*Met.*	22·97
Strontium,	Sr.	*Met.*	43·65
Sulphur,	S.	*Comb.*	16·00
Tellurium,	Te.	*Met.*	64·25
Terbium,	Tb.	*Met.*	—
Thorium,	Th.	*Met.*	59·83
Tin,	Sn.	*Met.*	58·82
Titanium,	Ti.	*Met.*	24·33
Tungsten,	W.	*Met.*	94·80
Uranium,	U.	*Met.*	60·00
Vanadium,	V.	*Met.*	68·66
Yttrium,	Y.	*Met.*	32·25
Zinc,	Zn.	*Met.*	32·53
Zirconium,	Zr.	*Met.*	33·67

15. When the elements of substances are expressed by symbols, the number of atoms of each element is indicated by small digits, placed under the symbol. Thus NO_5, which denotes nitric acid, shows that it consists of the two elements, nitrogen and oxygen: and that there are one atom of nitrogen, and five atoms of oxygen. Some chemists, would express nitric acid by NO^5; others, by $N+5O$. When compound atoms are to be indicated, their number is expressed by digits prefixed to their symbols. Thus, HO means a single atom of water: but 2HO means two atoms of water. A compound, formed by two or more substances, is—without supposing any particular combination of the elements, after they have been united—very *conveniently* expressed, by connecting their symbols with the sign $+$. Thus, SO_3+KO means sulphate of potash,

containing an atom of sulphuric acid (SO_3), and an atom of potash (KO): H_3, three simple atoms: 3HO, three compound atoms: $3(SO_3+HO)$, three atoms of a compound. We are not to confound chemical with mathematical symbols.

16. When an element enters into combination, in the proportion of one and a half to one atom of another, *sesqui** is prefixed to the name of the compound. Thus, *sesquioxide* of iron, contains the oxygen and iron, in the proportion of one and a half atom of the former, to one atom of the latter.

17. The atomic weight or chemical equivalent of a compound atom, is the sum of the equivalents of the atoms which constitute it. Thus, the atomic weight of sulphuric acid (SO_3), is 40. For S=16, and $O_3=8\times3$:—but $16+8\times3=40$.

We can find the amount of any ingredient of a compound by a simple proportion. Thus, of the potash, in sulphate of potash—

$$\left.\begin{array}{l}S = 16{\cdot}00\\ O_3 = 24{\cdot}00\end{array}\right\} = 40{\cdot}00 \left.\begin{array}{l}\\ \\ \\ \\ \end{array}\right\} = 87{\cdot}12, \text{ the atomic weight of sulphate of potash.}$$
$$\left.\begin{array}{l}K = 39{\cdot}12\\ O = \ 8{\cdot}00\end{array}\right\} = 47{\cdot}12$$

To find, from this, the quantity of potash in, for example, 2 lbs. 3 oz. sulphate of potash, say

$$87{\cdot}12 : 47{\cdot}12 :: \overset{\text{lbs.}}{2}\ \overset{\text{oz.}}{3} : \frac{2 \text{ lbs. } 3 \text{ oz.} \times 47{\cdot}12}{87{\cdot}12} = 1 \text{ lb. } 2 \text{ oz. } 12$$

dwt. 2 grs. nearly—or the potash, in 2 lbs. 3 oz. sulphate of potash.

18. Chemical Language.—Modern science has greatly simplified chemistry, by reducing its laws to a few great principles: and by arranging the compounds it affords, in a few great classes.

Compounds are *primary*, consisting of two elements: as water (HO), sulphuric acid (SO_3), &c. *Secondary*, consisting of two primary: as sulphate of soda (SO_3+NaO). *Ternary*, consisting of two secondary: as ordinary alum, in the dry state $[(SO_3+KO)+(3SO_3+Al_2O_3)]$. *Quaternary: as the same* alum, in the crystalline form $[(SO_3+$

* *Sesqui*, one and a half. Lat.

$KO)+(3SO_3+Al_2O_3)]+24$ *Aq.* &c. Primary, are sometimes called *binary* compounds. But the latter term is more correctly used to express a substance containing a single atom of one element, combined with a single atom of another: as water (HO). Hence, all binary are primary compounds: but not *vice versa*. As none but true binary compounds are decomposed, *primarily*, by the galvanic current [gal. 61], such decompositions may help us to discover what are, and what are not, binary compounds.

19. *Acids* are substances which redden litmus paper,* and form salts with oxides: the former test is, however, sometimes wanting: as, for instance, in silicic acid. The *radical* of an acid, is the element united with the acidifying principle. *Ox-acids* derive their acidity from oxygen; and are divided into those which have a simple radical, as sulphuric acid; and those which have a compound radical. The latter are subdivided into those whose radical consists of carbon and hydrogen, as acetic acid; those whose radical consists of carbon and azote, as cyanic acid; and those whose radical consists of carbon hydrogen and azote, as uric acid.

20. When two acids are formed from the same element, the name of that which has the smaller quantity of oxygen, ends in "ous;" as sulphur*ous* acid. And of that which has the larger quantity, in "ic;" as sulphur*ic* acid. When there are several acids of the same element, there are various modes of distinguishing them. Thus, some have the word hypo† prefixed to their names: as *hypo*-sulphuric acid, which has more oxygen than sulphurous, but less than sulphuric acid. *Hypo*-sulphurous, which has less oxygen than sulphurous acid. When an acid contains more oxygen than that which ends in "ic," it has *hyper*‡ prefixed to its name: as *hyper*-chloric acid, which is called, for brevity, *per*-chloric acid, and has more oxygen than chloric acid.

21. An *hydracid* derives its acidity from hydrogen. Many chemists now suppose that all acids are, in reality,

* Paper which has been tinted blue, with the colouring matter of litmus, a species of *Lichen*:—it is one of those called "test papers."

† *Hupo*, under. Gr. ‡ Huper, over. Gr.

hydracids: some being a combination atom for atom—as hydrochloric acid (HCl); and others, a combination of hydrogen with a compound atom—as oil of vitriol, which, if an oxacid, is SO_3+HO, but if an hydracid, SO_4+H. Hydracids, unlike some of the oxacids, never require water for their existence—that fluid merely dissolves them: and there is never more than one hydracid, of the same radical.

When the acidifying principle is sulphur, *sulph* is prefixed: as *sulph*-arsenious acid.

An organic acid, is briefly represented by the first letter of its name, with a line above. Thus, acetic acid, by $\overline{A}$.

22. *Oxides,* are substances formed by the union of elements with oxygen: the latter not being in such quantity as to produce acidity. The *base* of an oxide, is the element combined with the oxygen. Thus, lead is the base of oxide of lead. If the oxide restores the colour of litmus paper, reddened by an acid [19], it belongs to the class of substances, termed *alkalies:* in which case, it will also change the yellow colour of turmeric paper to brown, and will turn an infusion of red cabbage green.

23. If there are several oxides, formed by the same element combining with oxygen in different proportions, that which has the least oxygen is termed the *protoxide:** that which has the next greater quantity, the *deutoxide:*† that which has the next greater, the *tritoxide,*‡ &c.: and that which has the most, the *hyper* or *per-oxide* [20].

24. If a substance requires a larger quantity of oxygen, before it is capable of uniting with an acid, it is called a *sub-oxide.*

25. *Salts* are combinations of ox-acids with oxides: of sulph-acids with sulphurets: or, of the radical of the acid with the base of the oxide. The first are termed *oxy-salts,* &c., the second *sulphur-salts,* and the last *Haloid salts.*§ The *base* of a salt, is the oxide which is combined with its acid. Thus, potash is the base of sulphate of potash.

26. Sometimes, water acts the part of a base—forming

* *Protos,* first. *Gr.* † *Deuteros,* second. *Gr.*

‡ *Tritos,* third. *Gr.*

§ From *hals,* the sea. *Gr.*—Because sea-salt, consisting of *chlorine (the* radical of hydrochloric acid), and sodium (the base *of soda), is a type* of that class of salts.

a salt with an acid. And some chemists even suppose that many acids, ordinarily considered as mere solutions, are actually united with water so as to form a salt. Thus they consider oil of vitriol—a combination of one atom sulphuric acid, and one atom of water—as sulphate of water. When the latter constitutes the base of a salt it, occasionally, forms with the acid a crystalline compound. The basic water, very frequently, cannot be separated, but with great difficulty; and, often—unless it is replaced by some other substance—not without the acid being decomposed. This occurs with the nitric, acetic, and oxalic acids: which, no doubt, are salts of water.

27. Before water was discovered to constitute a base, it was found hard to understand the three phosphoric acids: which, if the water combined with them is not taken into account, contain precisely the same elements, although they have very different properties. But the difficulty disappears, if they are considered as *mono-basic*,* *bi-basic*,† and *tri-basic*‡ acids:—the first, being an atom of phosphoric acid and an atom of water; the second, an atom of phosphoric acid and two atoms of water; and the third, an atom of phosphoric acid and three atoms of water. Some of the basic water may be replaced, the rest remaining in combination. Thus, tribasic phosphate of soda, is an atom of phosphoric acid, two atoms of soda, and one atom of water; its crystals contain twenty-four atoms of water; and it throws down a white precipitate, if added to a solution of nitrate of silver. But, when this salt is exposed to a red heat, and then crystallized, its crystals are of a different form, and contain only ten atoms of water; and, if added to a solution of nitrate of silver, it will give a yellow precipitate. It has become, by the action of the heat, *bibasic* phosphate, termed *pyro*§-phosphate of soda: and contains an atom of phosphoric acid, united with two atoms of soda. Certain metallic oxides—thus alumina—act as bases towards strong acids, and as acids towards strong bases.

28. If the name of the acid of a salt terminates in "ous" *[20]*, that of the salt terminates in "ite:" thus, sulph*ite* of

* *Monos*, alone. *Gr.*
‡ *Tris*, thrice. *Gr.*
† Bis, twice. Lat.
§ Pur, fire. Gr.

lime, consists of sulphur*ous* acid and lime. But if the acid ends in "ic" the salt ends in "ate:" thus, sulph*ate* of lime, consists of sulphur*ic* acid and lime.

29. The salts of *proto*xides [23], are called *proto*-salts, &c.: those of the *per*-oxides, *hyper* or *per*-salts.

30. If the salt contains fewer atoms of the base than of the acid, the prefixes *bi*,* *tri*,† &c., are used. Thus, bi-tartrate of potash contains two atoms of tartaric acid, and one of potash. But, if the salt contains more atoms of the base than the acid, the prefixes are derived from the Greek. Thus, *di*-phosphate of magnesia contains one atom of phosphoric acid, and two atoms of magnesia. A salt is *basic*, when it contains more than one atom of base, provided some of the latter, has replaced "water of crystallization:" —basic nitrate of copper, consists of one atom nitric acid, three atoms oxide of copper, and one atom water.

31. The power of a base to saturate an acid, depends on the number of atoms of oxygen which it contains. Thus, protoxide of iron, having one atom of iron, and one atom of oxygen, saturates one atom of sulphuric acid; but, peroxide of iron, which has two atoms of iron, and three atoms of oxygen, saturates three atoms of sulphuric acid. The saturating power of the same acid, is found to be always the same. Hence, the quantity of any base, required by any acid, may be inferred from the quantity of oxygen, contained in the base of any one of the compounds of that acid, and the quantity in the given base. The amount of acid, sufficient to saturate a quantity of iron as protoxide, is incapable of saturating it as peroxide. Hence, the salts of the protoxide of this metal, which have a great tendency to absorb oxygen, always set some peroxide free, which falls to the bottom of the solution.

32. When a salt has neither acid nor alkaline properties, it is termed a *neutral* salt; if it reddens litmus paper, it is said to be an *acid* salt; if it restores reddened litmus paper, it is an *alkaline* salt.

33. From their resemblance to oxides, the compounds of elements with chlorine, iodine, bromine, and fluorine, are termed chlor*ides*, iod*ides*, &c.

Sometimes, oxides combine with chlorides, iodides, &c.

* *Bis*, twice. *Lat.* † Tris, thrice. Lat.

producing basic haloid salts—termed *oxy-chlorides*, *oxy-iodides*, &c. Thus, the oxy-chloride of copper, formed on the sheathing of ships, by the action of the sea water.

34. If a non-metallic element combines with another, with a metal, or with a metallic oxide, the name of the resulting compounds ends in "uret." Thus, sulphuret of iron, which consists of an atom of sulphur, and an atom of iron; *bi*-sulphuret of iron, which consists of two atoms of sulphur, and one atom of iron; sesqui-sulphuret of iron, which consists of iron and sulphur, in the proportion of one atom of the former, to one and a half of the latter. From their resemblance to sulphurets, compounds of the elements with cyanogen, selenium, &c., are termed cyanurets, seleniurets, &c.

Oxides sometimes combine with sulphurets, forming oxy-sulphurets: thus, oxy-sulphuret of antimony. Sulphurets combine with chlorides: thus, chloro-sulphuret of mercury.

35. If water unites with a substance, the result is called a *hydrate*:* thus, the hydrate of an acid. The water may even assume the solid form: as, in hydrate of lime. In such cases, heat—often very intense—is evolved. Hence, bottles have been burst, by the sudden generation of steam, arising from oil of vitriol being poured into them, after they had been rinsed with water, and not dried. Ships, laden with lime, have been burned at sea, on account of the heat produced by sea water leaking in, and slaking the lime. We have already noticed [heat 79,] that the specific heat of a body, depends on the space it occupies. When the water combines with the oil of vitriol, condensation occurs: and, by consequence, a diminution of specific heat. Also, when it combines with the lime, being changed from the fluid to the solid form, its specific heat is diminished.

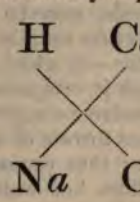
36. The combination of different quantities of water, with the same substance, occasionally produces marked differences, in the resulting compounds. Thus, seleniate of zinc unites with three different portions of that fluid, and assumes three different forms—according as, when crystallizing, it is hot, cold, or lukewarm. Water, united *with potash*, seems to act the part of a feeble acid:—we *have seen* [26] that it often acts as a base.

* *Hudōr*, water. Gr.

37. It may be proved that water combines *chemically* with bodies, by many examples. Thus, crystallized sulphate of copper ($SO_3+CuO+5HO$), exposed to a temperature of 150°, loses four atoms of the water; but the remainder is not driven off, even at 300°. The constitution of this salt is, therefore, $SO_3+CuO+HO$. This last atom of water may, however, be expelled by sulphate of potash: "a double salt" $[(SO_3+CuO)+(SO_3+KO)]$ being formed.

38. Water of crystallization, is represented by *Aq.** Thus, crystallized protochloride of tin, is $SnCl+3Aq$: anhydrous† or without water, it is $SnCl$. The three atoms of water, are those required for crystallization.

39. Chemical changes, which occur on mixing substances, are represented by very simple methods. Thus, $HCl+NaO=NaCl+HO$, means that, if hydrochloric acid (HCl), and soda (NaO) are mixed (in solution), the results will be chloride of sodium ($NaCl$), and water (HO). The same would be more fully expressed as follows:—



And, whenever a process is given in the former way, the student will do well, for his own improvement, to illustrate it in the latter, also.

The abbreviations of chemistry, whether those of language, or those which express substances, &c., are extremely useful: and should be both well understood, and carefully remembered.

40. Chemical Processes, are very numerous, and varied:—it will be proper to explain, here, the most usual and important, that no misapprehension may hereafter arise. The object of a chemical process may be, either

* *Aqua*, water. *Lat.*
† *A*, a privative particle; and Hudōr, water. Gr.

analysis,* or *synthesis*,† or a combination of both. Analysis, resolves a body into its elements: synthesis, forms i from them.

41. *Solution.*—A body is said to be dissolved, when being placed in a liquid, it loses the solid form, and ceases to be visible. If water is the solvent, the result is termed an "aqueous solution," or simply a "solution;"—and when no other solvent is mentioned, it is supposed to be water. If the solvent is alcohol, or ether, it is an "alcoholic," o an "ethereal solution"—or a "tincture." A solution i said to be "saturated," when it is incapable of dissolving any more of the solid. Sometimes the latter, on being dissolved, colours the fluid, or changes its colour.

42. Solution, is often employed to separate bodies Thus, if there is a mixture, containing substances which are soluble in a given fluid, and others which are not s those which are soluble will be dissolved out by, and may be removed along with it; while the insoluble will be left behind. Sometimes, a mixture of two fluids is employed Common salt, for example, may be separated from sulphate of lime, by a mixture containing one part alcoho and two or three of water—in which the sulphate of lim is quite insoluble, though it is sparingly soluble in wate alone. Some salts dissolve to a greater amount in ho than in cold water: thus nitrate of lead. Some, equall in cold and hot water: thus common salt. Some ar more soluble in cold than hot water: thus sulphate o soda.

43. *Maceration*, &c.—When the substance is dissolve out, without heat, the process is called "maceration. *Lixiviation*, is a combination of maceration and filtratio —a process to be explained presently. If the substanc to be acted upon, is left for some time in moderately warm water, it is called *digestion*; but if boiled with the fluid it is *decoction*. If, while the fluid is boiling, it is poure on a substance and left to cool, the process is said to b *infusion*.

44. Sometimes, the substance is changed during solu *tion*. Thus, oxide of iron, dissolved in hydrochloric aci

* *Ana*, severally; and *luo*, I set free. Gr.
† *Sūn*, together; and *tithmi*, I place. Gr.

becomes chloride of iron. Sometimes, even when the solvent is an acid, the substance is dissolved unchanged. Thus hydrochloric acid merely dissolves the oxalate or phosphate of lime: and may be separated from it, by the addition of a sufficient quantity of ammonia.

45. *Precipitation.*—When a body, in solution, is rendered visible, by being made insoluble, it is termed a *precipitate;* and is said to have been "precipitated," or "thrown down." This, in some instances, arises from a change in the nature of the solvent. Thus, when water is added to a solution of resin in alcohol, the resin separates, as a powder; for though strong alcohol will, dilute alcohol will not dissolve it. Sometimes, it arises from a change in the nature of the substance dissolved. Thus, if sulphuric acid is added to a solution of chloride of calcium in water, the chloride of calcium is changed into sulphate of lime, which, being insoluble, is precipitated.

46. The precipitate does not always sink to the bottom of the fluid; sometimes it remains mixed with it, or even floats. It occasionally assumes an appearance, not unlike that of a jelly—and is then said to be a "gelatinous precipitate."

47. Too much of the "re-agent," as the substance intended to show the presence of another is termed, must not be added:—in some instances, the precipitate is *redissolved by the excess.* On the other hand, there must be enough of it, or the nature of the result may be affected:—sulphuretted hydrogen, in small quantity, gives, with a solution of peroxide of mercury, a white, but in excess, a black precipitate.

FIG. 1.

48. *Decantation.*—The precipitate may sometimes be separated from the fluid, after having been allowed to settle *for a while,* by "decantation." That is, by

gently pouring off the liquor—which may be guided by a glass rod, represented by DE, fig. 1. Or may be prevented from running down the outer surface of the vessel, by besmearing its rim with tallow. When the precipitate is such as would be easily disturbed, a syphon [pneum. 53] may be used.

49. *Filtration.*—Sometimes it is necessary to separate the precipitate, by means of a "filter,"—which retains all the solid matter, and allows the fluid to pass through.

Filters, are either *single*, or *double;* and are formed of a cheap and peculiar kind of paper, containing no size. The paper is to be doubled twice, after being cut in the form of a square—the folds being at right angles; and that corner which presents four single leaves, is to be pared, so that, when the filter is opened—as represented by A, fig. 2, the edge of the opening will form a circle. It is to be placed—thus opened—in a glass, or porcelain funnel B. The latter may be fluted, or ribbed—that the fluid may escape more easily, between it and the paper. The liquid, containing the precipitate, will, on being poured into the filter, trickle down into jar D—represented of that form, which has been found most convenient for such purposes. The filter should always be previously wetted, with distilled water: without this precaution, some precipitates would pass through, at first.

FIG. 2.

50. A *double* filter, is made, by squaring, folding, &c., two pieces of paper, at the same time, instead of one: separating them, when made: balancing them in a pair of delicate scales: and paring the heavier, until both are exactly the same weight. Each of them is then to be *opened, as if* it alone were to be employed; and they are *to be laid,* one within the other, in such a way as that the *single side* of one shall be next the triple side of the ot

51. When all the fluid has passed through the filter, the precipitate must be carefully washed, by projecting upon it, distilled water, &c., according to circumstances. For this purpose, the washing bottle of Berzelius, fig. 3, will be found to answer extremely well—since it enables us to throw the fluid strongly against the substance to be washed. It consists of a glass tube A, drawn out fine at one end, and inserted into the cork of the bottle B, in which the distilled water, &c., has been placed. When B, having been gently heated on a stove, &c., is inverted—being held by the handle H—the temperature of the air contained in the upper part will be raised, by passing through the fluid. Consequently it will expand, and, pressing on the surface of the fluid, will force it out in a continued stream, which may be directed wherever it is required. Blowing into the bottle, and at the same time inverting it, will produce a similar effect, by condensing air over the surface of the fluid: but carbonic acid, from the lungs, might injure a delicate experiment: besides, most precipitates are washed more easily by hot than by cold liquids.

FIG. 3.

52. *Weighing a precipitate.*—When the precipitate has been well washed, which may be known by examination of the fluid passing through, the filters are to be cautiously folded up in some of the filtering paper: then to be placed on a porous stone, or in an oven, and exposed to a gentle heat: and afterwards, left for a while in the air—to re-absorb the hygrometric moisture they contained, when they were weighed* previously to being used. They

* As French weights and measures are so frequently referred to, in scientific works, the following may be useful to the student—

A metre = 39·37079 inches.
A litre = 1·76076 pints.
A gramme = 15·433 grains.

These are subdivided according to the decimal scale; and t

are, then, to be gently separated, and again weighed the difference of their weights, will be that of the pre tate, contained in one of them. Sometimes, it wil necessary to take out a portion of the precipitate, to w it, expose it to heat in a platinum crucible, and the ascertain how much weight it has lost: from whicl may calculate, by the rule of proportion, how much whole of the precipitate would have lost, had it been sible to separate it from the filter, and dry it—or ot wise act upon it by heat, in the same way.

53. When the weight of a precipitate is to be ascertai with but one filter, the latter, before being used, shoul dried to the same extent as it will be necessary to dry precipitate, which it is to contain: and, its weight b deducted from the weight of both it and the precipi the remainder will be the weight of the precipitate.

54. *Ignition of a precipitate.*—If the precipitate be ignited in the filter, one of exactly the same we must be ignited previously; and the ashes being weig their weight must be deducted from that of the ign filter and precipitate. The remainder will, of cours the weight of the ignited precipitate.

55. When the precipitate is to be merely dried, it be thrown on bibulous paper: or it may be gently he If it has been washed with water, it may be placed u the exhausted receiver, along with some strong sulph acid, or some fused chloride of calcium—either of wl on account of their affinity for water, will absorb vapour as fast as it rises.

56. Sometimes, particularly when the fluid is corro

subdivisions are indicated by the Latin prefixes *deci*, *centi*, Thus, a decimetre is the tenth part of a metre: a centimetre hundredth part of a metre: and a millimetre, the thousandth of a metre, &c. Tens, hundreds, thousands, millions of me &c., are indicated, respectively, by the Greek prefixes *deca*, *h kilo*, and *myria*. Thus, a decalitre, is ten litres: a myriagram a million of grammes, &c.

A *metre* is the ten-millionth part of a quadrant of the te trial meridian, measured on an arc which extended from B Iona to Dunkirk.

An are, the unit of superficial measure, is the square of a d *metre: and a stere*, the unit of solid measure, is the cube *metre*. *A litre* is the cube of a decimetre.

filtration may be effected by placing pounded glass in a funnel. The larger lumps are to be put underneath: then others, of a gradually diminishing size—fine powder being uppermost. Sulphuric acid, &c., can, in this way, be freed from the various impurities, which it may contain in the form of a sediment.

57. In some instances, it is necessary, during filtration, to exclude atmospheric air as much as possible. In such a case, the apparatus represented, fig. 4, may be employed. It consists of a vessel A, the upper part of which is connected, by means of the tube D, with the upper part of the vessel B. The aperture in the lower extremity of A is closed by linen, &c., placed in the neck. According as B fills, by the fluid passing through the linen, &c., the air within it ascends through D, and takes the place of what has descended from A.

FIG. 4.

58. *Edulcoration* is effected by washing away all particles, soluble in water, by agitation or trituration with that fluid; then decanting, and filtering.

59. *Elutriation* is effected when an insoluble body is, after being pulverized, agitated with water, and allowed to settle for awhile, until the larger particles subside: and the fluid is then poured off, and allowed to rest, until the impalpable powder has fallen: after which, the supernatant fluid is removed by decantation, &c.

60. *Distillation, &c.*—When the fluid, driven off by heat in the form of vapour, is to be preserved, the process is termed "distillation." The different temperatures at which different fluids boil, afford us a means, in many instances, of separating them by the application of a "bath" [heat 106]. For it enables us to regulate the temperature, so as not to exceed that required by the fluid, which is to be removed by distillation from others with which it may be mixed.

61. *Sublimation.*—If the vapour, obtained by distillation, is condensed in the solid form, the body is said to be "*sublimed.*"

62. *Destructive distillation.*—When, in obtaining gas eous or vaporous products, an organic body has its consti tution entirely broken up—new compounds being forme by its elements, it is said to undergo "destructive distilla tion."

63. *Fusion.*—If a solid body is changed by heat into liquid, the process is called "fusion." When crystal melt in their water of crystallization, it is termed "aqueou fusion;" and the resulting liquid is, in reality, a *hot* "so lution."

64. *Crystallization.*—Sometimes, a body is precipitate or sublimed, &c., in the crystalline form. In other cases it is necessary to evaporate the fluid, until that which re mains is no longer able to retain the whole solid matter i solution:—some of it will then be thrown down in th form of crystals. Common salt may, in this way, b obtained from brine.

65. When more of the solid is held in solution by hot than by cold fluid, if the solution is concentrated by evapo ration, and allowed to cool, crystals will be formed. And if these are removed, a fresh "crop" of them will be ob tained, by again concentrating, and cooling.

66. Crystals may sometimes be produced, also, by sub limation [61]. And, occasionally, the same body may b crystallized, either by solution or sublimation: but, in such cases, the crystals, which result from the two pr cesses, are rarely of the same form, and are often entir different:—such bodies are termed *dimorphous.** T more slowly crystals are formed, the more perfect t are. Sometimes, what is at first without a crystal form, may gradually assume it. Thus, melted suga when cooled, a hard, transparent mass; but, after months, it is opaque, and white—having become cry lized. In the same way, iron is found, in machines w are kept in rapid motion, to become crystalline, an its tenacity to a dangerous extent. This happens, some time, with the axles of locomotives: and is a for great caution, with regard to tubular and susp bridges, &c. Levers, &c., of the toughest iron, wh *subjected to* a considerable number of slight blows

* *Dis*, twice; and *morphē*, a shape. Gr.

riably break off, after a short time: and the crystalline structure extends, in all or most instances, to but a short distance from the fracture. The same substance may, in the same circumstances, produce crystals of different kinds. Hence, when crystals are left long in solution, they should be turned: or the growth may take place on some sides, more than others.

67. All crystalline forms are reducible to six systems—

First—The *octohedral* or *regular* system, having three *axes* of equal lengths, and at right angles to each other. Axes are lines passing through the centre of the crystal: and the different parts are symmetrically grouped around them.

Second—The *rhombohedral* system, which has three axes of equal length, in the same plane, and making with each other an angle of 60°; and a fourth unequal axis, at right angles to that plane.

Third—The *square prismatic* system, which has three axes at right angles; but only two of them equal.

Fourth—The *right prismatic* system, which has three axes at right angles; but no two of them equal.

Fifth—The *oblique prismatic* system, which has two axes making an acute angle with each other; and a third, at right angles to both.

Sixth—The *doubly oblique prismatic* system, which has all the axes of unequal lengths, and making acute angles with each other.

68. The various "secondary" crystalline forms, may be considered as produced from these six "primary," by having their new layers deposited unequally, at different sides. The most frequent change, arises from the replacement of a solid angle, or an edge, by a plane. Minerals having a *regular structure*, are capable of cleavage: that is, they may be split into parts, so that the detached surfaces will be smooth. When they are cleavable in two or more directions, they may often be made to assume forms which are regular, and very different from their original figure.

If a body, which separates from a fluid, &c., is not in the crystalline form, it is said to be *amorphous*.*

69. If a substance absorbs moisture, so as to become

* *A*, a privative particle; and morphē, shape. Gr.

liquid, it is said to be *deliquescent.* If, on the contrary, i loses water, so as to pass from the crystalline to the amor phous state, it is said to be *efflorescent.**

70. When a body is pulverized, by being rubbed, it i said to be *triturated.*†

71. A substance is *deflagrated,* by being exposed to high heat, with some other—nitre, for example—whic easily parts with its oxygen.

72. A body is *incinerated,*‡ when the coals, remainin after it has been burned, are reduced to ashes, by perfec and continued exposure to the air, while they are at a elevated temperature.

73. *Cementation* consists in surrounding a solid wit some other body; and exposing the whole mass, in a clos vessel, to a high heat, but not sufficiently so to cause fusio Green bottle glass is changed, by cementation with sand &c., into porcelain: iron, by cementation with charcoa into steel.

74. Chemical Apparatus.—Chemists, in their ex periments and researches, use a great variety of apparatu —a portion of which will be conveniently described here What is required for exceedingly interesting and importan illustrations, &c., is neither complicated nor expensive.

The following, of which some are more useful tha others, will be found quite sufficient, until a considerabl progress has been made:—

75. Glass rods. Tubes, both of common and of Berli glass—which bears a high temperature. Test glasses, o various forms, represented by A, B, E, and P, fig. 5. I may be held over a lamp, &c., by means of the handle H to which are attached slips of brass tightened by a loop a D—so as to suit tubes of different dimensions.

76. Bottles of various sizes: some of green, others o white glass; some with wide, others with narrow necks some with corks, others with ground glass stoppers—and

* From *flores*, flowers, *Lat.*; because, in the act of becomin pulverulent, they first present on their surface small needles, or powder, which—from some fancied resemblance—the older che mists termed "flowers."

† *Trito*, I rub. *Lat.*

‡ *Cinis*, a cinder. *Lat.*

Fig. 5.

few with *hoods* over the stoppers, for holding ether, and other very volatile fluids. Matrasses, like what is represented, fig. 6. We may remark here, that bottles, and other vessels, through which the air cannot pass freely, are to be dried, by heating them, and then sucking out the damp air through a tube—the process being repeated, until drops of moisture, are no longer condensed on the interior, by cooling.

Fig. 6.

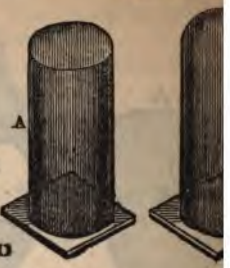
77. Glass receivers, of various shapes:—among others, globular, like A and D, fig. 7. The latter, is tubulated at H, and has a cork, or a ground glass stopper.

Fig. 7.

78. Cylindrical jars, like A and B, fig. 8, with ground edges—so as to rest air tight, on ground glass plates D, and E.

79. Plain and tubulated retorts—the former represented by H, fig. 9, and the latter by B. The tubulature is at A, and has a cork, or a ground glass stopper: D, and E are the beaks. Some of the Florence flasks, used for importing sweet oil.

Fig. 8.

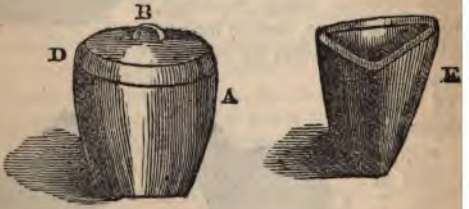


80. Wedgewood ware capsules, and evaporating basins: the former represented by A, fig. 1 [page 23]: and the latter by F. Also, if possible, a silver capsule.

Fig. 9.

81. A platinum crucible A, fig. 10, with a cover D. A lead crucible: one of silver: and another of black lead. Hessian crucibles, like E. A platinum spoon, an platinum foil.

Fig. 10.



82. One of the iron bottles used for importing m It should be fitted with a ground perforated sto which is attached a short tube of copper, termin one of block tin. The flexibility of the latter will *to be bent* with great facility.

83. One or two small charcoal furnaces. A rever

furnace fig. 11, is useful in experiments on the large scale. In it, the body to be acted on, is not exposed directly to the fire over A, but to the flame reflected down on it. It is introduced through an aperture, B: and stirred, or removed, through an aperture E, below the flue F: and is, therefore, kept free from ashes.

FIG. 11.

84. An argand lamp, and copper chimney. A spirit lamp, with a hood.

85. Funnels of glass, and porcelain—some plain, and others ribbed [49].

86. A safety tube P, fig. 12. If the air, within the retort E, when connected with a receiver, &c., becomes of an undue pressure, the small quantity of fluid, which is in the safety tube, being forced up into the funnel at P, the air will bubble through it, and escape. If, on the contrary, a vacuum happens to be formed, the fluid being driven into the bulb which is blown on the mid-

FIG. 12.

dle of the safety tube, the atmospheric air w
through, and enter the retort. In ordinary circu
nothing will pass through the safety tube; and
at any time, be poured, by means of it, into the

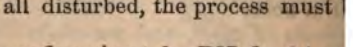
87. A sucking tube, AD, fig. 13, will be f
convenient, for removing most of the liquid over a precipitate—so as to facilitate the filtration: and if

Fig. 13.

it is used properly, the precipitate will not be i
disturbed. D, being introduced gently into the
mouth is to be applied, at A: and the fluid is to
up, until the bulb H is nearly full. The tongue
pressed against A, the instrument may be lifte
the fluid transferred to another vessel. If the
begins to be at all disturbed, the process must
at once.

88. A pipette or dropping tube, RN, fig. 14, m
in taking up, and transferring, small quantities of
this purpose, it should be immersed to a depth, which

Fig. 14.



depends on the quantity required; and, the th
placed on R, it may be withdrawn. The at
pressure, at N, will keep the fluid from falling
the aperture at R is unclosed.

89. Syphons [pneum. 53]. A washing bottl

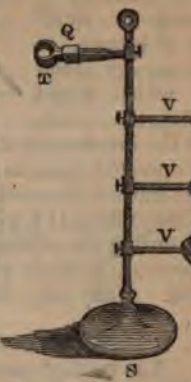
90. A brown-ware cask with porcelain coc
tilled water.

91. Pestles and mortars of Wedgewood war
and of steel. The steel mortar is cylindrical, w
able bottom: and the pestle fits it pretty accu
the substance, to be pulverized, may not be thr

92. A retort-stand S, fig. 15, containing mo
NN, &c., and an apparatus T—like what is a
the test glass B, fig. 5 [page 31]—for holding
of flasks, &c., while they rest on one of the

neath. A platinum crucible is represented as placed on wire formed into a triangle, and laid upon a ring—which, otherwise, would be too large for it. This apparatus may be rendered more simple—and still very convenient—by making a vertical rod, of wood, pass up, tightly, through corks, fixed in sockets, fastened to the wires V V, &c. No binding screws will then be necessary, to keep the rings in any required position.

Fig. 15.



93. Two sets of scales and weights:—one for coarse, and the other for delicate purposes.

94. Some bladders. Some sheets, and elastic tubes, of caoutchouc. The latter may be made, by drawing some sheet caoutchouc tightly over a piece of glass rod, or tube: then cutting off the parts that project with a *clean* scissors, and bringing together the severed edges—which will adhere firmly: and, if the process is properly managed, the joint will be very strong.

95. A spatula or elastic knife, with a blade of nearly uniform thickness, and blunt edges, fig. 16.

Fig. 16.

96. Rings, formed of strong wire, and well covered with strips of cloth, wound tightly round them, until they are from half an inch to an inch or more in thickness—according to their size. They are used as stands for globular vessels, flasks, capsules, &c.

97. Some iron, and copper, wire. Some files: and a soldering iron.

98. A *Blow-pipe*, is indispensable in the laboratory. It consists of a tapering tube DA, fig. 17, having at one end, a *large*, and at the other, an extremely small and *well-formed* circular aperture. The sphere, in the centre

vessel A, formed of tinned sheet iron —or, which is much better, of sheet copper tinned inside—and of a shallow cylindrical tray F, of equal diameter, supported immediately over, and at some little distance from it. A tolerably large tube, having a union joint above the tray, and a cock E between it and the vessel, passes down, water tight, from the centre of F, through the top of A, and reaches almost to the bottom of the latter. Another tube, fixed near

FIG. 19.

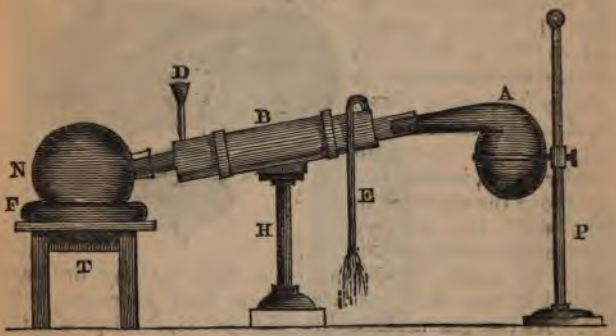
the former, is like it in every respect, except that it h no union joint above, and enters A without passing do for any distance through it. The cock P, is fixed outsi and very close to the top of A. The glass tube BD co municates, by means of short bent metallic tubes, with highest and lowest parts of the vessel. There is an ap ture at N, capable of being closed perfectly, by a pl which screws into it.

106. When gas is to be introduced into A, the co which are in the pipes forming a connexion between and the tray, are to be opened, the cock P is to be clos and the plug at N screwed in: water is then to be pou into the tray, until the vessel is filled. After this, cocks being closed, the plug at N may be removed, a the beak of the retort, or whatever else is to convey gas into A, may be introduced instead of it. Water w not escape at N, being kept in by atmospheric press [pneum. 44], until it is displaced by the ascending g and when it has all flowed out, the plug may be screw in again. If gas is to be taken from A, the cock E is be opened; and, water being poured into the tray, it w descend, and force out the gas through the cock P, as so as the latter is turned. P may be connected to a tube, The quantity of gas in A, can always be seen by the gl tube BD, the water in which stands at the same level, *what is* inside A.

107. The Distilling Apparatus, fig. 20, is used for *distillation* of water, acids, &c. It consists of a h

stand H, on which is placed—so as to be capable of making different angles with the horizon—a metallic tube B, of

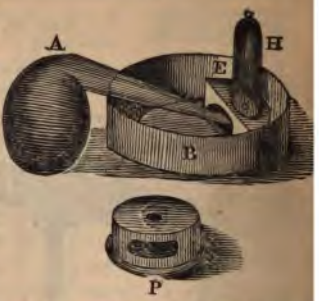
Fig. 20.



moderately large diameter, and closed at each end with a piece of cork, &c. A glass tube passes water-tight through the corks, and projects a few inches beyond them. A funnel D is placed, at one end of B; and a syphon E, at the other. The space between the metallic and glass tubes, is to be filled by pouring water in at D, until it begins to flow out at E. The lower end of the glass tube may be placed in the neck of a globular receiver N, resting in a ring [96] F, placed on the stand T; and the upper, may be connected with a retort A, in which is placed the water, &c., to be distilled, and which rests on the stand P. The vapour is prevented from escaping, between the end of the glass tube and the beak of the retort, by a piece of moistened bladder tied over them. As the vapour passes through B, it is condensed, and drops in the fluid state into N. The water in B is gradually heated; but the hotter portion, being the lighter [heat 17], ascends towards the higher end. As long as there is any cold water in the apparatus, it will be found at the lowest part: so that the vapour must pass through it, and be condensed. If cold water is poured in at D, it will drive the hot water up before it, and out through the syphon E.

108. Pneumatic trough.—Fig. 21 represents a simple

Fig. 21.



form of pneumatic apparatus. It consists of a porcelain or other vessel B, containing water. A jar H, having ground edges [78], is filled with water; then covered with the ground glass plate: and—being inverted—is placed, with its mouth under water, immediately above the aperture in the shelf E. A very convenient arrangement may be made, by means of a dish, or any ordin vessel of the kind, and a stand or shelf, represented P. As the gas ascends into the jar H, it displaces water—which descends: and H, when full, may be moved—the ground glass plate being previously slip under it.

109. Some gases must be collected over mercury, inst of water: but the mercurial pneumatic apparatus, dif from what we have described, only in being, genera speaking, smaller—on account of the weight, and dearn of the mercury.

110. *Wolf's apparatus*, consists of a bottle E, fig. having three necks. It is connected, by the bent gl tube H, with the retort which rests on the stand B; a by N and S, with the bottle R. The air-tight joint, at is made by placing a bit of caoutchouc tube [94] over two ends of the angular tubes that are to be united; a tying a thread round each end of it. P serves as a k of safety-tube [86]. The joint at T, being to some ext flexible, prevents the apparatus from being injured b slight derangement. Corks are fitted carefully into necks of E: and are rendered perfectly air-tight by a *luti* which may consist, according to circumstances, of plas *of Paris*, or putty. The latter, is termed *fat lute*, and *rendered* very secure, if a piece of wet bladder is tied o *it*. *Wax*, which is little affected by acids, may sometim *be conveniently* employed as a lute.

Sometimes, two or more bottles, like E, are used in the same experiment.

Fig. 22.

111. The application of baths, as a means of regulating temperature, has been already noticed [heat 106]. They are very frequently employed in chemistry, for producing a suitable and steady heat. Besides the *water bath*, called by the older chemists "balneum maris," or "balneum mariæ"—and which is exemplified in the better kinds of glue pot—a *sand bath*, also, is used. It consists of sand, placed in a vessel, under which is the furnace, lamp, &c.: —the retort, &c., to be heated, is placed in the sand. When coal gas can be had, a sand bath is seldom necessary.

112. In addition to the method of cutting glass already noticed [heat 20], circular pieces, like watch glasses, and extremely useful, may be cut from broken retorts, &c., by placing upon them metallic rings well heated, and then rapidly cooling the glass, by sudden immersion in mercury, &c.

113. Drills, files, &c., will cut glass with facility, if they are well rubbed with a solution of camphor in spirits of turpentine.

114. The end of a tube, &c., may be strengthened, so as *not to burst* when a cork is inserted in it, and its sharp

edges may be rounded, by keeping it for some time in a state of fusion with the flame of a blow-pipe.

115. AFFINITY.—We have seen [mech. 12] that there are various kinds of attraction. That which is termed *chemical affinity* differs from all others, on account of "changing the nature of the substances, upon which it acts." When very strong, it is accompanied by heat; and in many cases, by light, also.

116. The following are some examples of the effects produced by affinity—

Two gases will form a solid. If a glass cylindrical jar is held over a strong hydrochloric acid, some of the latter, in the form of gas, will ascend into it; and if a similar jar is held over water of ammonia, some of the latter will pass up in the same way—neither gas being visible. On placing the jars mouth to mouth, the two gases will combine together, and form sal-ammoniac, the minute crystalline particles of which, will cause the jars to be filled with what seems a white smoke.

117. Two fluids will form a solid. If sulphuric acid is added to a solution of chloride of calcium, sulphate of lime will be precipitated.

118. Two fluids will form an inflammable gas. This may be demonstrated, by mixing a small quantity of alcohol with excess of oil of vitriol, in a capsule; then heating the mixture in a flask; and, when all the common air has passed off, applying a lighted paper to the escaping gas.

119. Two fluids will give rise to spontaneous combustion. Nitric acid, mixed with a small quantity of strong sulphuric acid, will set fire to oil of turpentine, when thrown upon it. Since the combination is so violent, that some of the mixture will be scattered about, the acids should, for security, be poured from a small vessel, which has been tied to the extremity of a rod. The sulphuric acid strengthens the nitric acid, by combining with a portion of its water. It also takes up any of that fluid, which may be associated with the oil of turpentine.

120. Solids will give rise to spontaneous combustion. Loaf sugar triturated, and mixed with a small quantity of *chlorate of* potash, in powder, will inflame, if touched with *the end of* a glass rod which has been dipped in oil of

itriol. Or, some crystals of nitrate of copper moistened vith a drop of water, if *quickly*, and compactly, wrapped ıp in tinfoil, and placed on a stone, will burst into flame.

121. A solid and fluid will produce a spontaneously inlammable gas. This may be proved, by dropping dry hosphate of lime into water; or, throwing ether on a mall quantity of chlorate of potash, which has been moisened with oil of vitriol.

122. Two solids will cause explosion. Thus, a *very* ninute quantity of sulphur and chlorate of potash, rubbed n a mortar; or a *very* small bit of phosphorus rolled up vith a crystal of chlorate of potash, in paper, and struck ın an anvil, with a hammer. If there is no open side left n the paper: or, if the open side is turned towards the exerimenter, he will sometimes be injured, by the burning hosphorus which may be scattered about. To prevent uch an inconvenience, it is well to leave one side of the aper unfolded, and to turn the opening in such a direction, ıs that, whatever may be driven through it can cause no njury. Also, the hand in which the hammer is grasped, hould be wrapped in a cloth.

123. A solid and cold fluid will cause explosion and lame. Thus, a minute quantity of chlorate of potash, nixed with some phosphorus, or sulphur, and thrown into little oil of vitriol.

124. Combustion may be effected under water. Phoshorus will burn under warm water, if oxygen is thrown ın it, by means of a tube which leads from a bladder, or iled silk bag, a gentle pressure being applied.

125. Affinity changes or destroys colour. Solutions of ugar of lead, and of iodide of potassium, are clear and olourless: but when mixed, they are found to contain a eautiful yellow powder. Solutions of iodide of potassium, ınd of corrosive sublimate, also, are clear and without olour; but when they are mixed, a beautiful red powder s at once precipitated. Should either of the fluids be ıdded in excess, the red solid will be re-dissolved [47], ınd the solution will be colourless. If paper, rendered blue vith litmus, is held over the fumes of an acid, it will beome red; if it is then held over the fumes of ammonia, ts *blue colour* will be restored; and if, lastly, it is held

over water containing chlorine in solution, its colour will be permanently destroyed.

126. CIRCUMSTANCES WHICH MODIFY CHEMICAL AFFINITY.—Chemical affinity is modified by a variety of circumstances. Some elements have a tendency to unite only in the *nascent** state: that is, at the very moment of their being separated, by decomposition, from others, with which they had been combined.

127. *Quantity of matter* will affect chemical affinity. Thus, if common salt is added to water, it will be dissolved less and less rapidly, until at length the solution is saturated [41].

128. *Heat* will modify chemical affinity. Thus, hydrogen will restore heated oxide of iron to the metallic state, water being formed; but water will be decomposed by heated iron, oxide of iron being formed, and hydrogen being disengaged. In the former case, the hydrogen, and, in the latter, the iron, had the greater affinity for oxygen. If three substances are mixed together, two of them being capable of forming a compound more volatile than the third, that compound will be produced, and will be driven off by the heat. Thus, a mixture of lime and sal-ammoniac (hydrochloric acid and ammonia, or chlorine and ammonium), when heated, gives off ammonia. This principle may sometimes explain what occurs, when either of two substances may be decomposed, according to the circumstances. Sal-ammoniac, on applying heat, is decomposed by dry carbonate of lime, chloride of calcium and carbonate of ammonia being formed; although, if a solution of chloride of calcium is mixed with a solution of carbonate of ammonia, carbonate of lime and sal-ammoniac will be the result. Heat favours affinity, when a diminution of cohesive power is advantageous; but the contrary, when it gives rise to the gaseous form, either by separating the elements, or keeping them disunited—on account of the greater distance it places between them. Explosive mixtures are no exception to this law; since, probably, the very expansion caused by heat, brings some of the particles within the sphere of each other's attraction.

129. Partition of elements.—Affinities are sometimes

* *Nascor*, I am born. Lat.

modified by circumstances which might not be supposed likely to produce any effect: thus, the more difficult solubility of one of the compounds present in a solution. If, for example, spring water, containing hydrochloric acid, sulphuric acid, &c., soda, lime, &c., is evaporated, the sulphate of lime present, being very insoluble, will first be precipitated: then, although the sulphuric acid united with the soda is held in combination by strong affinities, a new division of it will take place, and more sulphate of lime will be formed—which, also, will be precipitated; and this process may go on, until all the sulphuric acid present is thrown down in combination with lime, notwithstanding the stronger affinity of the sulphuric acid for the soda than for the lime. In such cases, if the substance produced is very insoluble, the entire acid will be removed with such rapidity, that the effect will seem to be instantaneous—which occurs, when sulphate of barytes is formed by mixing nitrate of barytes and sulphate of soda. This principle may often modify the effect, when *double* decomposition occurs—that is, when two substances mutually decompose each other. It does not arise from greater force of affinity, since acetic acid will decompose carbonate of potash; although carbonic acid decomposes a solution of acetate of potash in alcohol. The potash being "divided" among the acids, carbonate of potash, which is insoluble in alcohol, separates as fast as it is formed. This division of each acid, among all the bases, and of each base among all the acids, though it does not always happen, occurs, undoubtedly, in many cases: and even when precipitation does not take place. Thus, if sulphocyanic acid is mixed with sulphate of iron, the solution will become of a blood red colour: showing that the stronger has given some of the iron to the weaker acid.

130. *Elasticity* modifies affinity, by causing repulsion, and thus driving off a portion of the elements. Hence [128], carbonate of ammonia will be given off from a mixture of carbonate of lime and sal-ammoniac, heated in the "dry state." At a high temperature, the least volatile acids have always the greatest tendency to remain in combination. The volatility due to increased temperature, *produces, on account* of the division of the elements among

each other [129], the same kind of effect as results from insolubility, when a precipitate is formed. This explains the expulsion of carbonic acid, by silex, in certain processes, to be noticed hereafter; also the hydrochloric acid driven off, when common salt is thrown on heated pottery; and the separation of water, at a high temperature, from substances for which it has a very strong affinity.

131. *Light*, as we have seen [opt. 120], affects affinity; and the results depend on the nature of the rays. If chlorine is exposed to ordinary light, it will, afterwards, in the *dark*, unite with hydrogen: except it has been subsequently exposed to red rays.

132. *Elective affinity.*—A substance may have an affinity for a number of others, but may choose one of them in preference to the rest. This is called "elective affinity." Thus, if mercury is added to nitrate of silver, it will be dissolved, and the silver will be precipitated in the metallic state. Copper will separate the mercury from the nitric acid, taking its place in the solution; lead will throw down the copper from the acid; and zinc will throw down the lead.

133. The order of affinities is different, with different substances. Thus, with sulphuric acid, it is

Barytes,	Lime,
Strontia,	Ammonia,
Potash,	Magnesia,
Soda,	Oxide of silver.

But, with hydrochloric acid,

Oxide of silver,	Strontia,
Potash,	Lime,
Soda,	Magnesia.
Barytes,	

Each acid will leave any substance, to combine with one that is higher on the list to which it belongs. Hence, the strong base, with one acid, may be the weak, with another.

134. A substance unable, by itself, to decompose a compound, may, in combination, have that power. Sulphate of barytes is not affected by potash, but it is partially decomposed, by carbonate of potash. The affinity of the carbonic *acid for the* barytes, assists that of the sulphuric acid for *the potash.*

135. Substances may decompose each other, without forming new compounds. Thus, oxide of silver, decomposes peroxide of hydrogen: and is, at the same time, itself, changed into metallic silver and oxygen. Substances may even affect chemical affinity, without, themselves, acting chemically. A small quantity of dilute sulphuric acid, boiled with starch, changes it into crystallizable grape sugar, without being itself in the least altered. Peroxide of hydrogen, is violently decomposed by finely divided platinum. Such effects, arise from a principle termed *catalysis*.*

136. Chemical substances may, by a species of infection, communicate new properties to others. Platinum, in any state of division, is insoluble in nitric acid; but a compound of platinum and silver dissolves in it. Copper, boiled with dilute sulphuric acid, does not decompose water; an alloy of copper, zinc, and nickel does—the copper being dissolved. It would seem that electrical action [gal. 22], ought to have preserved the platinum or the copper; but it appears that the chemical action is the more powerful.

137. Dyeing.—A knowledge of chemical affinity, is the foundation of the art of dyeing: since it enables the dyer to produce the various colours, and to render their union with the cloth permanent.

138. The substance to be dyed, whether woollen, linen, cotton, or silk, must be previously cleaned. When the cloth and the dye have little or no affinity, it is necessary to employ a *mordant*,† which, having an attraction for each, causes them to combine together. Calico printers used the solid excrements of the cow, to brighten and fasten their colours; but phosphate of soda is now employed, instead of it;—the efficacy of the excrements, being due to the phosphates they contain.

139. The most important mordants are alumina, the oxides of tin and iron, the tanin contained in nut-galls—which has a powerful affinity for cloth, and for various dyes, &c. Alumina is applied in the form of alum, or of acetate of alumina. The latter, answers better: since, when cloth is stamped with, or steeped in a solution con-

* *Kata*, severally; and *luo*, I set free. Gr.
† *Mordeo*, I bite. Lat.

taining it, and then merely heated, the acetic acid flies off, and the alumina, which remains behind, combines with the cloth, and subsequently with the colour also.

140. Sometimes, the whole cloth is soaked in the mordant, and the colour is then printed on, with blocks, &c.: after which the mordant is washed out—except in the spots, at which the colour has been applied, where it remains fixed. Sometimes, the cloth is steeped in the colouring matter, and the mordant is printed on, the colour being afterwards removed by washing—except where it has been rendered permanent by the mordant. When a white pattern is to be formed, the mordant is often removed, by the blocks containing the designs; and the cloth is then steeped in the colouring matter, and washed. Or, finally, the cloth is dyed of a uniform colour, and then stamped in patterns, with substances which destroy, or change it.

141. Different colours may, in some cases be obtained from the same dye, by the use of different mordants. Cochineal, with alum, will form a crimson; but, with iron, a black. Indigo requires no mordant; its solvent is sulphuric acid, and its colour is due to oxygen. It is of a greenish yellow, and is soluble in lime water, if deprived of its oxygen. It may be deoxidized, by the application of some substance having a greater affinity for oxygen—protoxide of iron, for example: but it will reabsorb oxygen from the atmosphere, and again become blue.

142. The Laws of Affinity.—It has already been remarked [9], that the elements do not combine in indefinite proportions. This fact is the great foundation of the "atomic theory," which has contributed so much to the advancement of chemistry; and which supposes, that the ultimate elements of bodies have a definite size, shape, and weight. What these are, can be only conjectured. A very probable notion of their shape, may, indeed, sometimes be formed: for, however small we break a body which crystallizes—carbonate of lime, in the form of Iceland spar, for instance—it still retains the same form. Consequently, if we could render it so minute in quantity, as that it would consist of but one compound atom, it is *natural to suppose* the shape of that atom, would be the *same as the* shape of the largest mass. Chalk, in the most

minute powder to which it can be reduced, is found under a powerful microscope, to be an assemblage of crystals, each as perfect as the finest specimen of calcareous spar.

143. The first law of chemical affinity is, that "the proportion in which substances unite chemically, is invariable." They combine atom for atom. Thus, if an atom of one element along with an atom of another forms a certain compound, an atom of one cannot combine with half an atom of the other—for there is no such thing; nor with two atoms, since its affinity is satisfied with but one.

144. The second law is, that "bodies, whether they consist of simple or compound elements, contain these elements in proportions that are some multiples of their atomic weights." That is, if an element enters into any combination, however complicated, with one or more others, their weights will be proportional to their chemical equivalents: or, as the chemical equivalent of one is to some multiple of the chemical equivalent of another. Thus, if a given compound consists of hydrogen and oxygen, the atomic weight of which are, respectively, one and eight, for every one ounce, or grain of hydrogen there will be found 8, 16, 24, &c., ounces, or grains of oxygen: or for every 8 ounces, or 8 grains of oxygen, there will be found 1, 2, or 3, &c., ounces, or grains of hydrogen. This law can be proved experimentally. If one equivalent of tartaric acid, and one of potash, each in solution, are mixed together, a soluble salt will be formed; but if two equivalents of tartaric acid and one of potash are the proportions used, bitartrate of potash, an insoluble salt, will be the result.

145. There are some apparent exceptions to the "law of multiples," as this is called. Thus there are two oxides of iron, the protoxide, the constitution of which is FeO, and the peroxide, the constitution of which is F_2O_3. The former, contains an atom of oxygen, for every atom of iron, and the latter, an atom and a half of oxygen for every atom of iron:—but an atom and a half is evidently not a multiple of unity, by an integer. There are two methods of explaining this apparent difficulty. We may consider that what is ordinarily taken as the equivalent of one atom of *oxygen, is in* reality the equivalent of two:—the prot-

oxide would then be FeO_2, and the peroxide FeO_3. Or, as frequently occurs with the oxides of iron and manganese, we may suppose that the peroxide is a combination of two oxides, one being FeO, the other FeO_2, and both together Fe_2O_3. Red lead, is an example of a compound, consisting of a peroxide and a protoxide.

146. The third law is that, "when one body unites with two or more different quantities of another, these quantities are to each other in a very simple ratio." This is well exemplified, as we shall see, by the compounds of nitrogen and oxygen—in which the oxygen is to the nitrogen as 1 to 1, as 2 to 1, as 3 to 1, as 4 to 1, and as 5 to 1.

147. Lastly, "gaseous substances unite in volumes." That is, "if two gases combine, it will be in proportions that are equal to, or multiples of some common volume." And it should be remarked, that, "the volume of the resulting compound, bears a simple ratio to the volumes of its elements." Thus, two volumes of hydrogen combine with one of oxygen, to form one volume of the vapour of water.

148. *Isomeric* bodies*, are those which consist of the same elements, in the same proportions; but differ in their properties. This difference may arise, in some cases, from their being differently grouped. Thus, sulphate of potash (SO_3+KO) may be considered as SO_4+K, SO_3+KO, SO_2+KO_2, $SO+KO_3$, or $S+KO_4$, &c.: and these different arrangements of the same atoms, were they to exist, might well be supposed to produce very different qualities. The three phosphoric acids, have been given as examples of isomerism; but we have seen [27] that, their water being taken into account, they are differently constituted.

149. The difference may arise in other cases, as in certain compounds of carbon and hydrogen, from the amount of condensation which occurs at the moment of production. Thus olefiant gas (C_2H_2) contains two volumes of carbon vapour and two volumes of hydrogen, which condense into one volume: and etherine (C_4H_4), four volumes of carbon vapour and four volumes of hydrogen, which condense into one volume. Oil of citron (C_5H_4) has the same constitution as oil of turpentine; but, when the former is

* *Isos*, equal; and *meros*, a part. Gr.

combined with hydrochloric acid, it becomes $C_{10}H_8$: while the latter, in the same circumstances, becomes $C_{20}H_{16}$. Again, alcohol ($C_4H_6O_2$) and methylic ether (C_3H_3O) each contain the same elements, in the same proportion; but the former can be resolved into ether and water: while the latter cannot.

150. *Isomorphous* bodies*, are those which have the same crystalline shape. We may infer [142] that their ultimate atoms also are, probably, isomorphous. But it is not universally true, that isomorphism arises from this cause. Thus arsenic acid (AsO_5) and phosphoric acid (PO_5) are said to be isomorphous, because each forms three classes of salt, which are, respectively, isomorphous. The arsenic acid itself, crystallizes in the *rhombohedral* [67]; and the phosphoric, in the *regular* system.

151. Bodies may be isomorphous, without having their angles exactly equal—which rarely occurs. Indeed the very same body, does not always crystallize, in precisely the same manner:—unequal heating, or cooling, may alter an angle.

152. Isomorphous bodies can be substituted for each other, without affecting the external character of the compound:—the atoms of the different elements will be the same in number, the crystals will remain of the same shape, &c.

153. Isomorphous bodies, easily crystallize together; and are separated with difficulty.

154. Certain bodies assume, in different circumstances, a difference of physical constitution. This is called, by Berzelius, the *allotropic*† state. Thus, sulphur is solid at one temperature, fluid at a higher, viscous at a yet higher, and liquid at a still higher. Iron, as we shall find, is rendered, by nitric acid of a certain strength, unalterable by oxidizing agents.

* *Isos*, equal; and *morphē*, a form. *Gr.*

† *Allos*, another; and *tropos*, a character. *Gr.*

CHAPTER II.

The elements of water. Oxygen, 155.—Combustion, 160.—Respiration, 172.—Hydrogen, 180.—Compounds of hydrogen. Water, 186.—Peroxide of hydrogen, 198.—The elements of atmospheric air. Nitrogen, 200.—Compounds of Nitrogen, 204.—Nitrous oxide, 215.—Nitric oxide, 218.—Hyponitrous acid, 220.—Nitrous acid, 225.—Nitric acid, 229.—Ammonia, 244.—Compounds of ammonia, 247.—Terchloride of azote, 257.—Carbon, 259.—Compounds of carbon. Carbonic oxide, 263.—Carbonic acid, 266.—Olefiant gas, 273.—Light carburetted hydrogen, 275.—Gases for illumination. Coal gas, 277.—Oil gas, 287.

155. THE ELEMENTS OF WATER. OXYGEN:*—*symb.* O.: *equiv.* 8. This substance was discovered by Priestly, in 1774. It has been called by different names—"dephlogisticated air," "eminently respirable air," "pure air," "vital air," "oxygenous principle:" and, finally, by Lavoisier, "oxygen," a term which is very objectionable, because founded on the supposition, that it is the only cause of acidity, an hypothesis long since proved to be at variance with the fact.

156. Oxygen is a most abundant, and highly important element. It forms, by weight, eight-ninths of water: and, by measure, nearly a fifth of the atmosphere: and is a constituent of stones, earths, &c.:—neither animals nor vegetables could exist without it. There are various modes of obtaining it. Peroxide of manganese (MnO_2), when heated, gives off one-third of its oxygen; and, when acted upon by sulphuric acid (SO_3), it yields twice as much—but the temperature required, is likely to break the retort. If the peroxide is merely heated, a combination of oxide and sesquioxide remains, after the oxygen has been liberated. This compound is analogous to black magnetic oxide of iron, formed in a smith's forge, and also when iron is burned in oxygen. If the manganese is acted upon by oil of vitriol, five atoms of the peroxide become, by a *gentle heat*, one atom of permanganic acid (Mn_2O_7), and

* *Oxús*, sharp; and *gennao*, I produce. Gr.

three atoms of protoxide ($3Mn O$). Exposed to a higher temperature, the atom of permanganic acid becomes two atoms manganic acid ($2MnO_3$), and one atom of oxygen. The heat being still further increased, the manganic acid is changed into protoxide: which unites with the sulphuric acid of the oil of vitriol, forming sulphate of the protoxide of manganese.

157. When oxygen is derived from manganese, it is more or less impure; but this is not the case when it is obtained by heating chlorate of potash ($ClO_5 + KO$). Two atoms of this salt, are changed into one atom chloride of potassium (KCl), and one, perchlorate of potash ($ClO_7 + KO$)—oxygen being evolved; and, when the temperature rises still higher, the perchlorate becomes chloride of potassium. Towards the end of the process, unless it is stopped, in time, the heat will be sufficiently great to melt the glass.

158. Oxygen may be procured, with great facility, by heating together two parts, by weight, chlorate of potash, and one part peroxide of manganese. The latter, seems merely to favour the formation of gas bubbles, but is not acted upon, itself. Other inorganic powders—black oxide of copper, for example—would answer as well for the purpose.

159. Oxygen is a colourless, tasteless, and inodorous gas; it is always electro-negative [gal. 61]: and is a non-conductor of electricity. Its specific gravity, is 1·1056: —100 cubic inches of it, weigh 34·2865 grains. Water absorbs about the one-thirtieth of its bulk of this gas. It is not inflammable, but supports combustion, and with great energy, when in a state of purity. If a taper, which has just been extinguished, the wick being still red hot, is introduced into oxygen, it will be immediately re-lighted. Charcoal, and phosphorus, in a state of ignition, burn brilliantly in it. If steel wire is formed into a helix, and a bit of thin iron turnings, which has been dipped in melted sulphur, is placed on one end of it, and ignited, it will burn in a jar of oxygen, with great splendour, and the emission of vivid sparks. If these precautions are taken, the experiment will be successful, even though the gas is not quite pure.

160. Combustion, to the ordinary observer, appears to be *the partial, or total* annihilation of the substance burned.

But, though a portion, or even the entire of it, disappears, it becomes invisible, only by giving rise to combinations which cannot indeed be seen, but are not the less real—since all of them may be collected, and examined. Chemically speaking, combustion is a union of the elements of the combustible, with the supporter of combustion—the latter being, in most cases, oxygen.

161. It was once thought that a substance, when burned, lost what was called *phlogiston*;* and the increase of weight, which is sometimes the consequence of combustion, was explained, by the gratuitous assertion, that phlogiston was the cause of levity.

162. The affinity exerted, during combustion, is, in many cases, so powerful, as to evolve heat, and even light. It is difficult, however, to account for these; since the ignited body occupies, after the combustion, a larger space than before; and, by consequence [heat 79], cold, rather than heat, should be the result. The difficulty cannot be removed, by saying that bodies having a less specific heat are formed:—since—as, when gunpowder is exploded—the specific heat of the compound generated, is often greater than that of the combustible: and, in no case, is the diminution so considerable, as to account for the phenomena. The more violent the combustion, the greater the heat, and the more intense the light—which, being, at first, blue, passes, as the temperature is increased, through various tints, until it finally becomes of the most dazzling whiteness. Heat and light are produced, by means of other supporters, besides oxygen:—they may be caused, even by the union of a combustible, with what is not ordinarily considered as a supporter. Thus, if sulphur is boiled in a matrass and, when the latter is filled with its vapour, a bit of copper leaf is introduced, great heat, and a brilliant light will be perceived; and sulphuret of copper will be the result. On the other hand, perceptible heat and light do not necessarily accompany combustion: this, as we shall find, is illustrated by the process of bleaching. Heat may be evolved without light—as in respiration; indeed, although not always perceptible, there can be little doubt that it is *invariably* the consequence of combustion. It will not be

* *Phlego*, I burn. Gr.

accumulated sufficiently to become apparent to the senses, unless the combustion is, to a certain degree, energetic.

163. Several conditions are required for perfect combustion. First, a combustible and a supporter are, evidently, indispensable:—the most inflammable substance, or the most powerful supporter cannot, of itself, give rise to combustion. Water extinguishes fire, simply, by placing the combustible out of contact with the supporter. Hence, persons whose clothes unfortunately take fire, should, instead of running about, and thus fanning the flame, wrap themselves up, at once, in a carpet, &c.—to exclude the atmospheric air. Fire, in a chimney, is extinguished, by a wet sack, &c., placed over the top of it—the supply of air being cut off. Combustion may be carried on, even under water, if the combustible and supporter remain, notwithstanding, in contact; for, as we have already stated [124], phosphorus may be burned under that fluid. Sometimes, the combustible and the supporter are found in the same substance—as, for example, in gunpowder.

164. Secondly, the combustible and supporter must be in the proper proportions [9]. If either is in excess, some of it will be left, and the combustion will be imperfect. The great degree of perfection which has, of late years, been given to lamps and furnaces, is principally due to a careful application of this principle, by securing a proper supply of atmospheric air—and therefore of oxygen. The atmospheric air merely *surrounds* the flame of an ordinary candle; but it is supplied to the *interior* of the flame of an argand burner, fig 23, and of candles with hollow wicks. If this supply is interrupted, smoke will immediately be emitted. The supply of air to apartments is, sometimes, so limited, on account of the tightness of the doors and windows, that there is not enough even to maintain a draught in the chimney [steam 15], which, consequently, smokes. One pound of carbon will require for its combustion, in ordinary circumstances, twenty-four cubic feet of oxygen: and will form twenty-four cubic feet of carbonic acid. It will require, at least, 300 cubic

FIG. 23.

feet of atmospheric air, to burn it properly—though t
oxygen contained in 120 would suffice.

165. *The Bude burner*, is constructed, in accordar
with this condition. It consists of two or more annu
tubes, furnished at the top with a number of apertur
from which the gas issues: each of them is raised high
than that which is outside of it: and all are connect
with one pipe. The light, from these circles of flame,
thrown in the proper direction, by means of reflecto
The *Bude light* is produced, by conveying oxygen in
the inner space of an argand lamp, so as to bring it in co
tact with the interior of the flame.

166. The burning fuel of a domestic fire is only su
rounded with atmospheric air; but the latter cannot ent
the flue belonging to the furnace of a steam-boiler, to supp
that which ascends, on account of its rarefaction, witho
passing through fuel in a state of ignition; and, as t
velocity, with which it moves, is dependent on the draugl
a current of air is formed, which produces the effect of
powerful bellows. It is on this principle, that a comm
fire is kindled rapidly, by means of the blower.

167. *Smoke prevention*, is effected by mixing a prop

FIG. 24.

quantity of atmospheric air with the gases which, if th
escape, constitute smoke. The principle on which it h
been effected, may be understood from fig. 24. B is t
boiler; and H, the furnace door. A firebridge of brick
placed between the ashpit and the space termed the "b

of distribution," into which the atmospheric air passes through a pipe, and from which, through a number of apertures, it flows into the mixing chamber D. Mixing there with the half-burned gaseous compounds of carbon and hydrogen, it causes them to be entirely burned, fuel being saved, and, if the quantity of air is properly regulated, smoke being totally prevented. In some cases, the fire-door itself is made to constitute a chamber, into which a regulated portion of air passes, and from which it issues, through the perforated tiles, of which the interior of the door consists.

168. Thirdly, the combustible and supporter must be properly mixed. The burning fuel, in an ordinary grate, is surrounded with abundance of oxygen: and yet, a large quantity of smoke escapes, through the chimney. A bellows renders the fire more energetic, by bringing the combustible and the supporter fully into contact. One of the most important points, in the manufacture of gunpowder, consists in carefully mixing the ingredients. When the combustible and supporter are very well blended, the resulting extremely rapid combustion is termed an "explosion." Combustion may often be produced, by an intimate admixture, when it would not otherwise take place. Thus, carbon, in a finely divided state, will ignite of itself:—this has, sometimes, caused gunpowder mills to be destroyed. Also, if oxide of iron, of nickel, or of cobalt, is reduced, at a low temperature, by a stream of hydrogen, the particles of the reduced metal, being extremely minute, will take fire spontaneously in the atmosphere. The button, in the interior of an argand burner, and often, the very shape of its glass—or metallic—chimney, contribute to throw the air into the flame, and mix it with the burning gases. This object is kept in view, also, in well-constructed furnaces.

169. Lastly, the combustible and supporter must be at a proper temperature. Charcoal, at ordinary temperatures, will remain unchanged, for an indefinite period. The smoke, escaping from a chimney, becomes, after a while, thoroughly mingled with the atmospheric air; but it is not ignited, since its temperature has become too low for that *purpose*. *Damp* fuel, does not burn well, because a con-

siderable portion of the heat is carried off, in the water which is vaporized. Hence, badly dried peat gives out but little caloric. Even fuel, apparently dry, may contain a large quantity of moisture. In recently-felled wood, from one-fifth to one-half its weight is water. Wood exposed to the air, for nearly a year, has been found to contain from 20 to 25 per cent. of that fluid. Wood charcoal, several years old, and kept for six months in a warm room, afforded 17 per cent. water. The flame, observed in burning charcoal which has been exposed to the air, is due to the decomposition of the moisture which it has absorbed, carburetted hydrogen being formed, and burned. With a proper supply of air, at a proper temperature, the smoke *must* be entirely consumed. When coal is first thrown into the furnace, it is placed just within the door, and is coked by the fuel near it, already in a state of intense ignition [steam 14]. The gases, as they pass off, mix with the atmospheric air—of which a proper supply has been secured, in the construction of the furnace—and, being at the requisite temperature for combustion, they inflame in their passage over the burning coals. In some recently constructed gas burners, which give a brilliant light, all these conditions are properly attended to: and the air, supplied to both the interior and exterior of the flame, is previously heated, by passing through wire gauze, fixed underneath it. This gauze, also, tends more fully to mix the gases.

170. The temperature, at which combustion occurs, generally affects the nature of the resulting compounds. When phosphorus is burned at that of the atmosphere, it takes three atoms of oxygen: but, when at a higher, five atoms. Alcohol, combined with oxygen, at ordinary temperatures, forms acetic acid: at those which are higher, carbonic acid and water.

171. If the combustion is very slow, the caloric may be dissipated as fast, or nearly as fast, as produced. Nevertheless, a certain amount of time is required for the economical combustion of fuel. Hence, the largest amount of *heat is*, practically, derived from the combustion of hard *woods*: though it should be obtained from the soft—since *those* which have the greatest excess of hydrogen, above

what is required for combination with the oxygen, ought to give the most heat. For, a given quantity of hydrogen, requires three times as much oxygen to burn it, as the same weight of carbon: and it is tolerably certain, that the heat given out in combustion, is proportional to the oxygen, which enters into chemical union. The hydrogen, therefore, ought to produce three times as much heat, as the carbon. Generally speaking, however, furnaces are so constructed, that the heat will not be properly absorbed, if generated with too great rapidity. When the lighter woods are used, large quantities of flame are produced, by the combustion of compounds of carbon and hydrogen; and less carbon is left to be burned when the flame has ceased. Should, however, a very intense fire be required —as in porcelain furnaces—the softer woods are preferred: but, to get from them as much heat as possible, proper arrangements must be made.

172. RESPIRATION.—A slow combustion is going on, perpetually, in the animal body. Atmospheric air, which is drawn into the lungs by what is called "inspiration," is expelled, in a very different state, by "expiration." During inspiration, oxygen is absorbed, and is carried, by the blood, through the entire body: during expiration, the carbonic acid, taken up by the blood, in its passage through the body, is evolved. A uniformity of temperature is secured, by the combustion being carried on in every portion of the body:—without this, one part might be intensely cold, while another would be inconveniently hot. Venous blood, which is of a dark colour, is, by giving off carbonic acid, and absorbing oxygen, changed into arterial blood, which is of a bright red. This change may be effected, even out of the body, by exposing the blood to air, or, what is better, to oxygen—particularly if it is agitated.

173. The blood, is admirably adapted for absorbing, either carbonic acid, or oxygen. It contains tribasic phosphate of soda, having two atoms of fixed base ($PO_5 + 2NaO + HO$): a salt which absorbs carbonic acid with great avidity, but gives it all off again, on exposure to the air. Some of the common salt, taken as food, changes the tribasic phosphate of potash—which renders the juice of *flesh decidedly acid*—into tribasic phosphate of soda; and

the chloride of potassium formed, passes off in the ur
Blood, is the only animal substance which has been fo
to contain iron: its colour being due to a salt of that me
of which we shall speak hereafter. The red particles, c
oxygen—as peroxide of iron—to the most remote porti
of the body: and this peroxide, meeting with hydrog
and with carbon in the nascent state—both which hav
strong affinity for oxygen—yield up to them the oxy
required for combustion. The iron is changed from
to *prot*-oxide—water, which passes off at the surface, be
formed, and carbonic acid, which is carried away by
blood, and evolved in the lungs.

174. It may be easily proved, that carbonic acid is gi
out from the lungs, by transmitting the expired air thro
lime-water—which will soon be rendered turbid, on acco
of the carbonate of lime that is produced, and rem
suspended in it. A healthy man spoils, in twenty-f
hours, about 726 cubic feet of atmospheric air:—the c
bustion of three ounces of charcoal, would do the sa
The absorption of oxygen, by the blood, was conside
by Fourcroi and other chemists, as necessary "to *irri*
the heart:" and to change the chyle from white to red
peroxidizing the iron. They attempted to account for
equable temperature of the animal body, notwithstand
that—in their opinion—the combustion took place onl
the lungs, by arterial having "greater capacity for he
than venous blood.

175. A correct idea of the process of respiration, le
to an easy mode of explaining several very important f
which, otherwise, are scarcely intelligible. Thus, in a
climate, where cold rather than heat is necessary, the
consists principally, of substances, such as fruits, wh
contain little else than water: and which, so far from
tributing to raise the temperature of the body, actually
duces it, by afterwards, to a great extent, passing off in
form of vapour. In cold countries, on the contrary,
food—meat, for instance—is rich in carbon, and o
highly combustible matter. And the Esquimaux, in gl
ing over their tallow candles and train oil, as the grea
delicacies, are only complying with an instinct, which l
them to select that nourishment which is best suit

their condition. One of the reasons, on account of which bleeding is advantageous in inflammation, &c., is, that the red particles—which may be termed the "oxygen carriers" —being diminished, the supply of oxygen throughout the body is lessened; and, in the same degree, the evolution of heat. And, further to prevent combustion as much as possible, food rich in combustible matter, or that which is likely to augment the quantity of red particles, is carefully avoided.

176. It would seem that vital heat, and muscular energy, are simultaneously developed by combustion within the body; and their *simultaneous* production, appears to be necessary for good health. Hence, when liquids containing alcohol are used, heat is generated, not, as it should be, by a change of the tissues, but by the combustion of alcoholic vapour. For, alcohol has the peculiar property of passing freely through the body, in a state of minute division—which [168] is highly favourable to chemical combination; and it is not, like other food, assimilated by the process of digestion. It was found by Prout, that alcohol, and fermented liquors, diminish the amount of carbonic acid, formed by respiration. The blood, therefore, is robbed of that oxygen, which should have gone to effect a gradual and healthy change of the tissues; and the combustion—being due to a substance which is unconnected with the body—is the cause of heat, but not of muscular energy. The effects of this are obvious, in those who drink to excess:—they have not the proper digestive power, and are visited with all the evils, which ought naturally to flow from the want of a proper amount of muscular vigour.

Exercise accelerates the action of the lungs, increases the amount of combustion—and, consequently, the quantity of heat produced: but, as it causes the tissues to be more quickly consumed, it renders their more rapid replacement necessary—and thus increases the appetite.

177. The fat of animals is a store of combustible matter, destined to be used on extraordinary occasions. It soon disappears, in starvation; and, after it, the muscular flesh: —but the tendons are not consumed, in any extreme of *want*. *Hibernating* animals, carry with them, to their

winter retreats, as much fat as is sufficient to supp
languid existence, which expends so little energy, an
quires so small a quantity of heat. As might be expe
persons soon die, under the influence of both cold and
ger. For, the effort made by the body, to meet the der
arising from increased combustion, renders the const
tion greater, and a supply still more necessary.

178. The respiration of reptiles, by means of tubes,
of fishes, by means of gills, is founded on the same pr
ple as that which is effected in the lungs. And it is wo
of remark, that the air which is disengaged from wate
heat, is richer in oxygen than the ordinary atmosphe
since it contains thirty per cent. of that gas. This, p
ably, is intended to facilitate respiration, carried on
comparatively imperfect apparatus. The low temper
which accompanies the less perfect respiration of the l
orders in the animal kingdom, is what ought natural
be expected. Vital heat is, in human beings, sen
affected by imperfections in the respiratory organs, ar
from disease, or otherwise: also, by the rapidity, or s
ness, of respiration, and by the quantity of red blood.

179. Carbon is not separated from the blood, by
agency of the lungs only. A large portion of it is remo
in the shape of bile, by the liver—the action of which
therefore, been termed "*hepatic** respiration;" and
some respects, its functions are subsidiary to those o
lungs.

180. HYDROGEN:†—*symb.* H.; *equiv.* 1. It was
scribed by Cavendish, as "inflammable air," in 1776.
forms, by weight, one-ninth, and by measure, two-th
of water; and constitutes a large portion of animal
vegetable substances. Hydrogen, may be obtained
variety of ways. It will be evolved, if iron, or zinc—
quite pure [gal. 16]—is dissolved in dilute sulphuric a
sulphate of iron, or of zinc, being left in solution. (S
HO)+Fe=(SO_3+FeO)+H; and, (SO_3+HO)+Z
(SO_3+ZnO)+H. The acid must be diluted, since
strong affinity for water will not allow the latter to b
composed, unless it is present to a certain amount;

* *Hepar*, the liver. Gr.

† *Hudōr*, water; and *gennao*, I produce. Gr.

sulphate of the protoxide of iron, is not soluble in strong sulphuric acid. The gas obtained, is more pure, when zinc is employed. We may obtain hydrogen, likewise, by acting on a metal with hydrochloric acid (HCl) :—hydrogen is evolved, and a chloride of the metal is left in solution. When zinc, for example, is used $HCl+Zn=ZnCl+H$.

181. Hydrogen, is a colourless gas; and, when quite pure, has neither taste nor smell. It is the lightest substance known, its specific gravity being 0·0693:—100 cubic inches of it, weigh 2·149 grains. On account of its lightness, it has been used for the inflation of balloons [hyd. 40]; but coal gas, though much heavier—its specific gravity being about 0·4—is now employed for the purpose, from the ease and economy with which it is procured. It is obvious that when coal gas is employed, to obtain a given amount of buoyancy, a balloon of large size is required. The difference between hydrogen and coal gas is, however, not so great as might be supposed: since the hydrogen used with large balloons contains water in solution, which adds very much to its weight. Considering its density, hydrogen is a high refractor. It is very sparingly soluble in water. It is inflammable, but not a supporter of combustion, nor of respiration—though it may be breathed for a short time, without any other consequence than rendering the voice shrill and small [pneum. 65]. This might be expected, from the diminished density of the vibrating medium, acted on by the organs of the voice.

182. We may prove that it is inflammable, but does not support combustion, by inverting a jar which is filled with it, and putting up into it a lighted taper. The latter will be extinguished, when within the gas, but will be relighted as it passes through the portion which is in contact with the atmosphere—and which, therefore, has been inflamed. Since the gas is lighter than common air, it will remain in the jar, though inverted—for a lighter cannot descend through a heavier fluid [hyd. 43]. When hydrogen is pure, the flame it produces is colourless.

183. It appears, from the researches and reasonings of chemists, that, although it seems to form acids, it, in reality, produces salts—being, it is supposed, a highly volatile *metal*. According to this opinion, when iron, which has

stronger affinity than hydrogen for chlorine, is acted upon by hydrochloric acid (HCl), the chloride of hydrogen is merely changed into chloride of iron ($FeCl$). If hydrogen is really a metal, it is easy to account for the amalgam formed, by means of the galvanic battery, with ammonia (NH_3) and mercury. It would not be the only metal known in a state of very subtile vapour. The probability that hydrogen is a metal, is increased by the resemblance found to exist between the salts of water, and those of zinc, and of copper.

184. If the materials, used for evolving hydrogen, are placed in a gas-bottle, stopped with a cork containing a tube of glass—drawn out fine at the end which projects externally—and the gas, as it escapes, is ignited, what has been called the "philosophical candle" will be produced. And, when the flame is held within tubes of different diameters, and consisting of glass, metal, &c., musical sounds —not, however, of a very pleasing description—will be heard. They arise from the successive explosions which, in reality, constitute the flame, and which cause the air to vibrate within the tube. Since these explosions follow each other with a certain degree of rapidity, the effect on the senses of sight, and hearing, is [pneum. 75: and opt. 165] continuous. The intervals of silence perceived, are due to the columns of hot and cold air not being completely in unison [pneum. 98]. It is necessary, before lighting the gas, to allow the common air within the bottle to escape: or an inconvenient, and even dangerous explosion will occur.

185. Hydrogen forms, with oxygen, two oxides—water (HO: 9·0), and peroxide of hydrogen, or oxygenated water (HO_2: 17·0). It combines, also with other elements. The most important of the resulting compounds shall be examined, at the proper times.

186. Compounds of Hydrogen. Water, *symb.* HO or *Aq.*; *equiv.* 9. It is always produced, when hydrogen is burned in atmospheric air, or oxygen: two measures of hydrogen and one of oxygen, produce two measures of the vapour of water. We can prove synthetically, as well as *analytically*, that it consists of oxygen and hydrogen, by *holding a cold* surface in the flame of burning hydrogen:—

the water, formed during the combustion, will be deposited in drops upon the surface. Since it occupies a vastly less space than the gases which constitute it,—only one measure of water being produced by 3,000 measures of the mixed gases—the collapse of the air explains, to a certain extent, the noise heard when an explosive mixture is inflamed: as, for example, when the electrical pistol is fired, and the bladder [elect. 81 and 82] is burst. A lighted taper, applied to an aperture made in the bladder by a pin, would have produced the same effect as the electric spark. Such an experiment, exemplifies the danger, which must arise, when hydrogen, or certain of its gaseous compounds —such as coal gas, or the vapour of ether, which also form, with oxygen, or atmospheric air, explosive compounds—are brought in contact with a lighted candle.

187. *Davy's lamp.*—Davy was led to the principle of his safety-lamp, by finding that if two bladders are filled with an explosive mixture of gases, and are connected by a tube of a sufficiently small diameter, the explosion of one will not produce an explosion of the other bladder. The lamp, which bears his name, was invented by him to secure miners, &c., from the dangerous accidents to which they are exposed, by explosive mixtures of common air and the gas constantly liberated from coal in mines. It depends on the fact, that flame—which is gas at a white heat—will not pass through small tubes, or apertures, such as are formed by the wire-gauze, with which the "safety-lamp" is covered. For, it is cooled down by the angles and edges of the gauze; and, even if the latter becomes red hot, it continues incapable of igniting the mixture—which is gradually, and without any risk, consumed within the lamp. The intense heat will, however, if the mixture is highly explosive, after a while oxidate the gauze, and make it fall to pieces:—an explosion would then ensue. In such cases, the flame of the lamp is first extinguished; and the inflammable gases burn on the interior of the gauze.

188. A current of ignited gases, may be made to pass so rapidly through the gauze, as not to be sufficiently cooled to prevent explosion.

189. The destruction of life, consequent on explosion in

mines, arises, in many instances, from the subsequent
of oxygen, and the enormous quantities of carbonic
from the high temperature, often due in a great degr
ignition of the coal dust in the passages: and from
terrible tempests produced. When the mixture of
contains more than fourteen or less than seven volum
atmospheric air, an explosion cannot occur. Expl
mixtures are sometimes formed by the gas liberated
coal in the holds of ships, &c., and the most disas
consequences sometimes occur, from the introductio
lighted candles in such circumstances. Explosive mix
are formed, also, from the gas allowed to escape from
in houses: and whenever, from the smell, danger is
pected, a light should not be introduced.

190. If oxygen and hydrogen, in the proportions w
constitute water, are thrown, during combustion, on
substance, they form what is called the oxy-hydrogen
pipe [103]: and afford an intense heat. If their fla
thrown upon lime, or chalk—which, under its influ
soon becomes lime—a light of the most dazzling brill
is emitted. It is called the "oxy-hydrogen lime-l
[opt. 56: and gal. 54], or "Drummond's light"—sinc
are indebted for it to the late Mr. Drummond, who
the light afforded by some of the earths, when inte
heated, in geodetical observations: and* suggested it
plication to lighthouses. For the former, he prefer
stream of oxygen, thrown on the burning vapour of alc
and, for the latter, a mixture of oxygen and hydrog
combustion. A jet of oxygen, thrown on the flam
spirit lamp, will give a very great heat, and the comp
flame thrown on lime, an extremely brilliant light.
Drummond light has been visible at the distance of at
seventy miles. Its brightness is due to the fact, tha
ferent substances emit, at the same temperature, lig
very different intensity. Thus, in the experiment al
mentioned [184], while the flame of the burning hyd
is scarcely perceptible, the extremity of the glass
whence it issues, though not more strongly heated, i
The intense light, emitted by certain solids raised to
temperature, enables us to understand why hydrogen,

* Phil. Trans. 1826.

bined with carbon, gives a more brilliant light, though less heat, than hydrogen by itself. For the elements of water, having the stronger affinity, will unite, before there is sufficient oxygen present to combine also with the carbon:—the latter will, therefore, be precipitated in the flame, and intensely ignited. The feeble light of burning carbonic oxide is due, in part, to the fact, that no solid particles of carbon are deposited in the flame. If there is air enough—as in the argand burner [164]—it will, as it ascends, gradually combine with oxygen. Hence, the middle of the flame will give carbon; but the bottom, or top, of it none. The same principle explains why zinc, or phosphorus, burns with such splendour—the solid results of combustion being ignited. The brilliancy of light may be diminished, or destroyed, by a combustion so rapid, that there may not be time for the solid particles to be deposited: as when a small jet issues with great velocity into the atmosphere; or when, on account of its excessive length, the draught of an argand chimney is too great—the heating power being, in these cases, proportionally increased.

191. Great care must be taken, in the combustion of oxygen and hydrogen, that the gases do not unite, except in small quantities, and just before being inflamed. Many ingenious contrivances have been devised, for security against the danger of their explosion. Fine wires are placed lengthways in a tube of metal: and the interstices, which act as tubes of extremely small diameter, are still further diminished, by driving a plug strongly into the middle of the wires. This apparatus, however, impedes the passage of the gas considerably, and it will not prevent explosion, unless made with very great care. Sometimes the mixed gas is conveyed through the water with which a small vessel is partially filled:—fluid is thus interposed between the flame and the reservoir. If the small quantity, which is over the water, should explode, no mischief can occur: since, either the vessel is made very strong, or a cork—which acts as a kind of safety-valve—is merely blown out. Very commonly, the hydrogen is placed in a gas holder, fig. 19 [page 38], and the oxygen in a similar *one of half the size*—the two vessels being connected, by

means of an arched tube, the extremities of which are attached, respectively, to the union joints, placed on the upper ends of the tubes passing down through their centres [105]. When water is poured into a funnel, inserted into the highest part of the arched tube, it enters each vessel, and forces out the gases through the cocks—one of which is seen at P: whence they are conveyed to the jet, and are mixed just before being inflamed. As the two columns of water in the gas holders are of the same height, the pressures are constant and equable [hyd. 8]: and there is no tendency in either gas to pass into the other vessel, and thus form an explosive mixture.

192. The mutual affinity of the elements of water, gives to us a means of reducing certain oxides. Thus, if a stream of hydrogen is passed through heated oxide of copper, water and metallic copper will be the result. This, as we shall find, enables us, in the analysis of organic substances, to estimate the quantity of hydrogen which they contain.

193. If a stream of hydrogen is thrown on spongy platinum—procured by dissolving platinum in a mixture of nitric and hydrochloric acid, then precipitating it with sal-ammoniac, and heating the precipitate—it unites with the oxygen of the atmosphere so rapidly, that it causes the platinum to become sufficiently hot to set the gas on fire. This principle has been used, as a means of obtaining light, instantaneously. Faraday has remarked that, if platinum is connected with the positive, and, sometimes, even with the negative pole of a galvanic battery, it will afterwards cause the constituents of water to combine. The same effect will be produced, if it is rendered perfectly clean, with sulphuric acid, and subsequent washing in distilled water. This property—which has been shown, by Dulong and Thenard, to belong to all the metals, earths, &c.—arises, according to Faraday, from the attraction of those substances for the gases: the particles of which are thus brought within the sphere of each other's attraction. For a similar reason, the presence of a solid body facilitates crystallization [heat 47]. The combination of the gases is always accompanied by the evolution of heat, and often by *explosion.*

194. A substance in the state of decomposition will cause

the mixed gases to combine. This effect is due to a chemical principle we shall notice hereafter:—the inertia of the molecules is overcome, by an external force, derived from actually existing chemical action. The same result is obtained whether, or not, carbonic oxide—which is found to arrest the action of spongy platinum—is present.

195. No natural water is quite pure; since it always holds in solution the substances it has carried with it, from the strata through which it has passed. Peas, &c., boiled in hard water, become covered with a thin coating of lime, which prevents the water from entering them, and making them soft: boiling the water, previously, prevents this. Alkaline waters, are those which contain alkalies: such are the geysers in Iceland. Saline waters, contain the neutral salts. Sulphurous waters contain sulphuretted hydrogen, or the sulphuret of a metal, &c. Chalybeate waters contain carbonate of lime, or carbonate of iron, dissolved in the carbonic acid which is in the water. When the oxide, belonging to the carbonate of iron, is peroxidated by the oxygen of the atmosphere, it can no longer remain in combination with the carbonic acid. It is therefore precipitated: and constitutes the red sediment, which is observed in chalybeate springs, and the streams issuing from them.

196. Water is capable of dissolving a variety of substances to a greater or less extent [41]. It will leave one substance, to combine with, or dissolve another. Alcohol will precipitate nitre, from water holding it in solution. Hydrochloric acid will, in the same way, throw down chloride of barium, by combining with the water which dissolved it.

197. Water is capable, also, of absorbing many gases: among others, atmospheric air [steam 54]—which is given out again by boiling. Since the air, which is required for the respiration of fishes, &c., is obtained from the water, it is sometimes necessary to break the ice, that it may be renewed:—without this precaution, the fishes would die. The presence of atmospheric air, in water, greatly hinders the absorption of other gases:—for a small quantity of a sparingly soluble gas will expel, or prevent the absorption, of a large, but corresponding quantity of a very soluble gas.

Fish will not live in the lakes of mountainous regions—as the water does not retain enough air, in solution.

198. Peroxide of Hydrogen: *symb.* HO_2: *equiv.* 17. This is a very curious, though not a very important substance. To obtain it, pure barytes is peroxidized, by heating it along with an equal weight of chlorate of potash. When oxygen begins to be disengaged from the chlorate, a brilliant red glow commences at one point, and spreads over the whole mass. The hydrate of the deutoxide of barium ($BaO_2+Aq.$) is separated, by washing, from the chloride of potassium: and is added to dilute hydrofluoric acid, until acidity is removed. Fluoride of barium and peroxide of hydrogen are the results. $HF+BaO_2=BaF+HO_2$. The fluoride and excess of peroxide of barium are separated, by filtration, from the dilute peroxide of hydrogen; which is then placed under an exhausted receiver, along with sulphuric acid [heat 93], to remove the water. If left too long under the receiver, the peroxide itself will evaporate.

199. Peroxide of hydrogen is a thick, colourless, and caustic liquid, of a disagreeable taste. It parts with oxygen very easily; and, therefore, bleaches, &c.: and is very energetic, unless greatly diluted. Many solids violently resolve it into water, and 475 times its bulk of oxygen: and often without being changed themselves—which is particularly the case with peroxide of manganese. Sometimes, the oxygen of the peroxide, instead of becoming free, enters into combination: as when oxide of lead is used. It is decomposed rapidly, by fibrine; but not at all by albumen. Its specific gravity is 1·452. If kept long, even diluted, oxygen is liberated spontaneously, until at length nothing but water remains.

200. The Elements of Atmospheric Air. Nitrogen:*—*symb.* N.; *equiv.* 14·02. Atmospheric air consists, principally, of nitrogen and oxygen. The latter, has been already examined. Nitrogen, which is also called "azote,"† was discovered by Rutherford of Edinburgh, in 1772; and was ascertained to be an element of atmos-

* *Nitron,* nitre; and *gennao,* I produce. *Gr.*

† *A,* privative particle; and zōē, life, Gr.:—from its being *incapable of* supporting life.

pheric air, by Lavoisier, in 1775. It is found in great abundance: and constitutes about four-fifths of the whole atmosphere: as, also, a large portion of many animal, &c., substances. It may be obtained by several processes. If a receiver is inverted over a capsule, floating on water, and containing burning phosphorus, the oxygen of the common air will combine with the phosphorus, and form phosphoric acid (PO_5). The latter will be, at first, in the state of white fumes—consisting of minute crystals, suspended in the nitrogen: and, after a little while, on account of its deliquescence, will be dissolved by the water in which the receiver stands. Nothing will then be left, along with the nitrogen, except some vapour of phosphorus and a little carbonic acid—both which may be removed, by passing the mixture through a solution of caustic potash: and some aqueous vapour—which would be taken away, by transmitting the gas through fused chloride of calcium, or strong sulphuric acid.

201. Nitrogen is colourless, tasteless, and inodorous. Its specific gravity is 0·976:—100 cubic inches, weigh 30·2674 grains. Its characters are merely negative. It is not a combustible, in the ordinary sense; though if it is mixed with hydrogen, and set on fire, a green flame will be produced, and the water derived from the combustion, will be found to contain nitric acid (NO_5). The latter will be formed, also, by passing electric sparks through moist atmospheric air: as may be proved by wetting litmus paper with the solution of an alkali, and taking a succession of sparks with it. The paper will be reddened, at the point where the sparks are taken: and, if it is dried, and ignited, it will show—by burning like touch-paper—that nitrate of potash (NO_5+KO) has been formed. Nitrogen is not a supporter of combustion—nor, consequently, of respiration. We may take this opportunity of remarking, that irrespirable gases are of three kinds. The "narcotic," which produce torpor—as sulphuretted hydrogen: the "irritant," which produce inflammation of the lungs, &c.—as ammonia; and the "neutral," which are injurious, only from the absence of oxygen—as nitrogen. The larynx closes spasmodically against certain gases: which *are then said, in* ordinary language, "to stop the breath."

This happens with chlorine, carbonic acid, &c. When such gases are diluted, to a certain extent, with common air, they enter the lungs: and cause, as the case may be, an irritant, or a narcotic effect.

202. Some—among others Sir H. Davy and Berzelius—have supposed nitrogen to be a compound substance. The chief argument, in favour of this hypothesis, is that ammonia (NH_3), as we have already remarked [183], will, under the influence of the galvanic battery, along with mercury, form an amalgam. Which would seem to indicate that NH_4O (NH_3+HO) is the oxide of a metal: unless it is admitted, that so light a body as hydrogen is metallic [183]. This argument is, however, questionable; since Gay Lussac, and Thenard, assert that, even though moisture is absent, the amalgam will, on breaking contact with the battery, resolve itself into ammonia, hydrogen, and mercury. Also, it has been considered by some chemists, as very unlikely, that all the nitrogen found in the muscles of graminivorous animals, is derived, as nitrogen, from vegetables—which, therefore, they suppose must contain its elements. Whence it would follow that it is a compound.

203. The affinities of nitrogen—except in the nascent state—are not very strong. It forms, with oxygen, nitrous oxide (NO: 22·02); nitric oxide (NO_2: 30·02); hyponitrous acid (NO_3: 38·02); nitrous acid (NO_4: 46·02); and nitric acid (NO_5: 54·02). It forms, with hydrogen, ammonia (NH_3; 17·02.) With chlorine, terchloride of azote (NCl_3; 120·43), &c.

204. Compounds of Nitrogen. *Atmospheric* Air.*—It is doubtful whether, or not, this is a compound, or merely a mixture:—the latter is the more probable. It is tasteless, inodorous, and, when in common quantities, without colour. It is a bad conductor of electricity. Being the standard of comparison for the gases, its specific gravity is represented by unity. Compared with distilled water, it is 0·00122: and is, therefore, 820 times lighter than that fluid. If the barometer is at 30 inches, and the *thermo*meter at 60°, 100 cubic inches of atmospheric air, *free from* moisture and carbonic acid, weigh 31·0117 grains.

* *Atmos*, vapour; and *sphaira*, a sphere. Gr.

The height of the atmosphere has been estimated at 45 miles: and its temperature decreases one degree, for about every 352 feet of ascent. This decrease, is due to its greater distance from the earth, which heats it by contact; —also, its specific heat being increased by its rarity [heat 79], it requires a larger quantity of caloric, to raise it to a given temperature. Poisson supposes the air, in the upper regions, to be so cold as to be actually frozen: in which case, our earth and atmosphere would be contained in a shell of frozen air. But the cold of the planetary spaces has been shown, by Fourrier, not to be lower than −57°, which is met with, at Melville Island, in winter, and is often exceeded by artificial means; while at the lowest temperature we can produce, atmospheric air does not show any tendency to become even a fluid—much less a solid.

205. The quantity of oxygen in the air is constant. Hence, to suppose that the salubrity of a climate depends on the amount of that gas, contained in its atmosphere, is erroneous. As to the miasmata which cause, or disseminate disease, they have, hitherto, proved too subtile for chemical analysis. Air, brought by Gay Lussac from an elevation of 21,790 feet—reached by a balloon—was found to contain exactly the same relative quantity of oxygen as that near the surface of the earth. An instrument for ascertaining the quantity of oxygen, in the atmosphere, is termed a "eudiometer."* It has been variously constructed. Spongy platinum [193], mixed with clay—to prevent its action from being too sudden—and let up into a graduated glass jar, which contains common air and hydrogen, and stands over mercury, forms a simple and very excellent one. The diminution of bulk, arising from the union of hydrogen with the oxygen, is to be noted: and one-third of it, is to be considered as having been occupied by the oxygen which has disappeared, and which belonged to the atmospheric air under examination.

206. Another kind of eudiometer, consists of a glass tube, bent until the two parts are parallel, and hermetically sealed at one end. Two fine platinum wires are

* *Eu, well or right*; and *Dios*. Gr. A name for Jupiter, and *applied also, to the air.*

inserted into opposite sides, near the sealed end—the glass being fused around them. An ascertained quantity of common air is placed, along with some hydrogen, in the sealed end of the tube: and, outside of the hydrogen, mercury—some space being left, next the open end. When the latter is closed with the thumb, and an electric spark is transmitted through the wires, so as to explode the gases, the elasticity of the air next the thumb will prevent the mercury from being blown away. After the explosion, the diminished space occupied by the gases—the residue of which consists of hydrogen and nitrogen—may be determined. One-third of what has disappeared was oxygen.

207. The proportion of nitrogen, in the atmosphere, has been variously estimated:—it is about four measures in five. If it is replaced by an equal quantity of hydrogen, life will be supported, but the animal will fall asleep.

208. The rarity of the atmosphere, in hot climates, causes a smaller quantity of oxygen to be contained in a given space:—hence the lungs, and their auxiliary the liver [179], are over-worked, in producing a given effect. And—according to a provision, which makes any part of the animal body thrown into more frequent or energetic action, to increase in size—the liver becomes diseased, from augmented bulk. The rarity of the atmosphere, also, makes breathing painfully difficult, on very high mountains.

209. It is an object of interest, to ascertain if the gases, which constitute the atmosphere, are chemically combined, or only mechanically mixed. Their proportions are favourable to chemical union: being about one to five, by measure: and one to three and a half, by weight. But the density, specific heat, &c., of the atmosphere, are the mean of those belonging to its constituents; and the synthetical production of it, gives rise to none of those changes, which, in a greater, or less degree, are found to accompany chemical action:—there is no condensation:—no evolution of heat: nor are any qualities subsequently perceived, which *might not* be expected from a mere mixture. The difference between the densities of the two component gases, *is no obstacle* to their mixture. For Dalton found, that

if a heavier gas is placed in the lower bottle, of two connected by a tube, it will soon be equally diffused through both. This tendency—as was first ascertained by Priestly—is not prevented by the interposition of a membrane; and it extends even to fluids. The passage of gases, or fluids, in this way, has been termed "endosmose,"* and "exosmose."† Two currents are established, between the gases or fluids of different densities: the lighter, generally, having a tendency to dilute the heavier. Dalton believed that vapours, and gases, diffuse themselves through space, as if each alone were present: and that they offer only mechanical obstacles to each other:—and he established his opinion, by an experiment already mentioned [heat 109]. He found that as much of the vapour of each was within the receiver, as if all the rest were absent.

210. The velocity with which gases diffuse themselves through each other, and, also, the times, required by them for entering a membrane, or a porous body, are inversely as the square roots of their specific gravities.

211. Their tendency to diffuse themselves through each other, may be illustrated, by closing a vessel, containing hydrogen, with a sheet of caoutchouc. The hydrogen will pass out, more quickly than the common air will enter; and the caoutchouc will be bent inwards so much, that it will ultimately burst.

212. There occurs, in wine countries, a curious example of the ease with which gases permeate membranes, and animal tissues. A poisonous wine, called "feather white wine," is deleterious, merely because it is still in a state of fermentation, which is increased by the heat of the stomach. The disengaged carbonic acid, penetrates through the body to the lungs, from which it expels the atmospheric air, and thus causes asphyxia. Inhalation of ammonia, is the best remedy for the effects of this wine.

213. Besides nitrogen, the atmosphere contains also carbonic acid (CO_2), ammonia (NH_3), and the vapour of water. Carbonic acid, is found even on the highest mountains: it is more abundant in summer, than in winter; at night, than in the day; and in gloomy, than in clear

* *Endon*, within; and ōsmos, impulse. Gr.

† *Ek*, out of; and ōsmos. Gr.

weather;—a moist ground, succeeding rain, diminishes quantity. The ammonia of the atmosphere is derived fr animal and vegetable substances. Liebig ascertained presence, by evaporating a large quantity of rain water, which a little hydrochloric acid had been added. Cryst of sal-ammoniac (NH_4Cl) were produced. He detec it also, in snow water, by the addition of hydrate of li The amount of watery vapour contained in atmospheric is determined by the principles of hygrometry [heat 95

The relative quantities of the ordinary constituents the atmosphere, may, on an average, be considered as low:—

	In 100 parts, by volume.	In 100 parts, by weight.
Oxygen,	20·935	23·146
Nitrogen,	77·418	75·567
Carbonic acid,	0·045	0·068
Vapour of water,	1·602	1·219
	100·000	100·000

Atmospheric air has never been liquefied.

214. *Ozone*,* which, as we have already noticed [el 104], is present in the atmosphere surrounding an elec fying machine, is found also in the oxygen evolved f water decomposed by the galvanic battery. Its nature not yet been ascertained. Air containing it will, chlorine, a substance we shall examine hereafter, libe iodine from iodide of potassium; and it will change yell into red prussiate of potash. It is decomposed, or remo by the presence of organic matters.

215. Nitrous Oxide:—*symb.* NO: *equiv* 22·02. is obtained, by heating nitrate of ammonia (NO_5+NH which melts into a liquid at 300°: is decomposed, at 3 and is entirely changed, by heat, into nitrous oxide water. $(NO_5+NH_4O)=2NO+4HO$.

216. Nitrous oxide, is a colourless gas, of a plea taste, and an aromatic smell. Its specific gravity is 1·5 100 cubic inches, weigh 47·3549 grains. It is absor by an equal volume of fresh boiled water:—and henc prevent its being wasted, is collected over a saturated s *tion of common* salt. It is nearly as good a supporte

* *Ozo*, I smell. Gr.

combustion as oxygen—being decomposed, and yielding that substance, to the elements of the combustible. It may be breathed for a short time: and has a very extraordinary effect upon many persons. Generally speaking, when inhaled, it causes great exhilaration of spirits, a flow of vivid ideas, very pleasurable sensations—not followed by the languor which succeeds every species of intoxication—and a great tendency to laughter. On account of the latter, it has been called the "laughing gas" of Sir H. Davy, by whom it was discovered. Its action on persons of different temperaments, is, however, various: but it is rarely disagreeable, and never dangerous—provided a pure gas is used. If the same portion is passed too frequently through the lungs, its properties are entirely changed by respiration; and the carbonic acid, derived from it, would, if inhaled, cause asphyxia [212]. The presence of sal-ammoniac, in the nitrate of ammonia, would render the gas pernicious, by giving rise to the production of nitrous acid, and chlorine. Hence, the nitrate should be formed for the purpose:—about two ounces of it, would produce gas enough to affect one person.

217. Nitrous oxide can be deoxidated, and pure nitrogen be obtained from it, by heating nitrate of ammonia in a tubulated retort; and, when the salt melts, pushing down into it a bit of zinc, which has been previously attached to a copper wire, passing through a cork in the tubulature. Nitrous oxide and zinc, form nitrogen and oxide of zinc. $NO+Zn=N+ZnO$.

218. Nitric Oxide:—*symb.* NO_2; *equiv.* 30·02. It is produced, when a metal is acted on with nitric acid. To obtain it, a mixture, consisting of equal volumes of water and nitric acid, is to be poured on copper filings, or small bits of copper: and heat is to be applied, until the action commences:—after which, the gas will continue to be disengaged copiously. Nitric acid and copper form nitrate of copper, and nitric oxide. $4NO_5+3Cu=3(NO_5+CuO)+NO_2$.

When iron is dissolved in dilute nitric acid, without the evolution of gas, water and nitric acid are decomposed, oxide of iron (FeO), and ammonia (NH) being produced. $NO_5+3HO+8Fe=8FeO+NH_3$.

219. Nitric oxide is a colourless gas; but, since it c not be brought into contact with oxygen without be changed, neither its taste, nor smell, if it have any, ca ascertained. Its specific gravity is 1·041:—100 c inches, weigh 32·2832 grains. It is sparingly absor by water at 60°. It is not a combustible; nor, excep a few instances, a supporter of combustion:—carbon phosphorus, however, when vividly ignited, become n brilliant in this gas, which is decomposed, by the temperature, into nitrogen and oxygen. It cannot course, be respired, without becoming mixed with oxy

It may be changed into nitrous oxide, by being lef some time in contact with moist iron, or zinc, filings.

220. Hyponitrous Acid:—*symb.* NO_3; *equiv.* 3 Of all the gases, nitric oxide, only, has the property being mixed with oxygen, of becoming an orange vap some of this vapour is hyponitrous acid. Oxygen, t fore, and nitric oxide, are *tests* for each other. Henc we suspect either to be present, we have only to intro into it a small quantity of the other—or of some gas w contains it, and our doubt will at once be removed.

221. Pure hyponitrous acid may be obtained, by mi four measures of nitric oxide and one of oxygen— dry; and liquefying the resulting orange vapours, by Liquid hyponitrous acid, is the nitrous acid of contin chemists. Whether hyponitrous, nitrous, or nitric will be formed, singly, or together, on mixing nitric o and oxygen, depends not only on the relative quanti the gases, but also on circumstances seemingly immat —such as the diameter of the tubes, &c., employed— rapidity with which the mixture is made—the time allo after mixing—the amount of agitation—and whethe oxygen is added to the nitric oxide, or the reverse, &

222. Hyponitrous acid, in the state of vapour, h very disagreeable taste, and a suffocating smell; neither a combustible, nor a supporter of combustion. absorbed by water, giving rise to nitric acid and n oxide. $3NO_3=2NO_2+NO_5$. If much nitric acid is sent, nitric oxide is formed, and nitrous acid—which co *the fluid, to* an extent dependent on the quantity. $2N$ NO_2+NO_4. The specific gravity of this acid, in the

of vapour, has not been satisfactorily ascertained. At a temperature of 0°, it becomes a colourless, and at —8°, a deep green liquid. Hyponitrous acid, in the fluid state, is highly volatile: and evaporates in the form of orange vapours. The acid properties of this gas, may be shown, by attaching a small piece of litmus paper to the interior of a jar, filling the latter with water, then inverting, and letting up into it four volumes of nitric oxide, and one of oxygen:—the moment the latter is introduced, the paper will be reddened.

223. Priestly discovered that water, holding hyponitrous acid in solution, becomes dark brown, and opaque, by the addition of sulphate of iron.

224. A compound, containing hyponitrous acid, cannot be produced directly, since that acid is decomposed, whether in the gaseous or fluid state, by contact with water; —it may, however, be formed, indirectly, by keeping nitre (NO_5+KO) melted for some time. Two atoms of oxygen will be given off, and hyponitrite of potash will be formed. $(NO_5+KO)=(NO_3+KO)+O_2$.

225. Nitrous Acid:—*symb.* NO_4; *equiv.* 46·02. It is obtained by heating finely-powdered, and well-dried, nitrate of lead (NO_5+PbO), to full redness. The nitric acid separates from the oxide of lead; but, as it cannot exist without water, it is immediately decomposed into nitrous acid and oxygen. The red vapours, as they are evolved, are condensed into a liquid, by a mixture of snow and salt; and the free oxygen passes off. $(NO_5+PbO)=NO_4+PbO+O$.

226. Nitrous acid vapour, is orange red; it is irrespirable, causing great irritation, and spasm, of the glottis. It supports combustion brilliantly; burning sulphur is, however, extinguished by it. Since one volume of it contains one volume of nitrogen (=0·976), and two of oxygen ($2\times1·1056=2·2112$), its specific gravity should be 3·1872 (=0·976+2·212). The vapour, if passed into a jar of atmospheric air, will, on account of its greater specific gravity, displace the air. It cannot be collected over water, which changes it to nitric acid and nitric oxide. $3NO_4=2NO_5+NO_2$. This arises, from the affinity of *water to nitric acid.* But, if this affinity is satisfied, by the

presence of a sufficient quantity of that acid, the nitrous acid is not decomposed: and the fluid is bluish, bluish-green, green, yellow, or orange—according to the relative quantities of nitrous acid, nitric acid, and water. The nitric oxide, formed by decomposition of the nitrous acid, escapes with effervescence: unless the quantity of water is small, in which case, the fluid merely becomes of a green colour. Nitrous acid cannot be collected over mercury, since it would be decomposed—the metal being oxidized.

227. Liquid nitrous acid, has a specific gravity of 1·451. It is nearly colourless at 0°: is orange yellow at 60°, and becomes a white crystalline solid at —40°. It boils at 82°, producing a red vapour which, at 212°, is quite black [opt. 112]. If the bottle which contains it is not stopped, it will evaporate rapidly, at 60°.

228. It was at first supposed, that attempting to unite this acid with bases, would merely give rise to nitrates, and hyponitrites:—and hence it was inferred to be only a combination of nitric and hyponitrous acids ($2NO_4 = NO_5 + NO_3$): but it has been ascertained that it is capable of forming salts.

229. Nitric Acid:—*symb.* NO_5; *equiv.* 54·02. It is obtained by pouring 98 parts, by weight, of concentrated oil of vitriol (SO_3+HO) on 101·14 parts of well-dried nitre [nitrate of potash; (NO_5+KO)]; and applying heat. The nitric acid distils over, and bisulphate of potash—double sulphate of potash and water $[(SO_3+KO)+(SO_3+HO)]$—remains in the retort. $(NO_5+KO)+2(SO_3+HO) = [(SO_3+KO)+(SO_3HO)]+(NO_5+HO)$. In the commencement of the process, orange vapours are evolved: for, common salt ($NaCl$) being present in the nitre as an impurity, hydrochloric acid (HCl) will be liberated by some of the sulphuric acid: and, as we shall find hereafter, will be decomposed by, and decompose a portion of the nitric acid. Likewise, some of the nitric acid is decomposed, by the sulphuric acid combining with its water. At the end of the process, also, orange vapours will be evolved, from some of the nitric acid being decomposed, on account of the high heat:—when this occurs, the process *should be stopped.*

230. It depends on the quantity of sulphuric acid used,

whether sulphate, or bisulphate of potash will be left in the retort. It is better to form the bisulphate, since it is the more soluble, and may be removed, without much difficulty: while the retort will, most probably, be broken in attempting to take away the sulphate. When enough sulphuric acid to form the bi-salt is employed, the nitric acid takes half its water, and is distilled off, at from 266° to 269°. By itself, it boils at 106·8°; but all the acid would not, with that temperature, be separated from the bisulphate.

231. If only enough sulphuric acid to form sulphate of potash is used, the process is more complicated; for, then, only half the nitre is decomposed, and only half the nitric acid obtained—a mixture of nitrate and bisulphate of potash being formed, which is not decomposed so as to yield nitric acid, and become sulphate, until the temperature rises to 400°. And, at first, a weaker nitric acid is disengaged, on account of the high heat decomposing some of it, the water of which goes to the rest. As the process advances, the acid becomes stronger; but towards the end, the very elevated temperature decomposes nearly the whole of it, into oxygen, and nitrous acid—which [226] is dissolved by the nitric acid in the receiver, particularly when the latter is kept cool.

232. If the nitre is not well dried, before being used, the water *mechanically* mixed with its crystals, would weaken the nitric acid. A small quantity of organic matter in the nitre, would decompose some of the acid; also, the presence of a comparatively large quantity of sulphuric acid—which, before it would have time to unite with the potash, would take away some water.

233. Nitrate of soda (NO_5+NaO) has almost entirely superseded nitrate of potash, in the manufacture of nitric acid. It is cheaper; it affords a larger product; and does not require so high a temperature, nor so much sulphuric acid. 100 parts nitrate of potash, contain only 53·41 nitric acid: while 100 parts nitrate of soda contain 63·56.

234. When the sulphuric acid is cautiously poured into the retort, the nitric acid will be quite free from it. Any which may be present, however, and also any iron—generally found in the nitric acid of commerce—may be re-

moved, by rectifying (redistilling):—they will be left behind, if the process is not carried too far. The apparatus, fig. 20 [page 39], may be used, both in the manufacture, and rectification. Chlorine, if detected, may be separated by nitrate of silver: which will form water and chloride of silver, a white powder, from which the acid may be decanted.

235. Nitric acid has never been insulated:—that is, it has never been procured, except united with water, &c. It may, sometimes, be obtained, in combination with but a single atom of that fluid—its specific gravity then being 1·521. It is, generally, found to have a specific gravity of 1·500: in which case, two atoms of the acid are combined with three atoms of water. When its specific gravity is 1·35, it does not act on tin, nor iron, unless they are touched with another metal, while immersed in the acid. It will not act on lead, or tin, if concentrated; but if it is diluted with water, violent action is, at once produced. Nitric acid, is a powerful oxidizing agent. This was sufficiently evident, when [119] it was poured on oil of turpentine:—water and carbonic acid were produced, with such violence, that ignition was the consequence. Charcoal boiled in nitric acid becomes carbonic acid; sulphur would become sulphuric acid, and phosphorus, phosphoric acid, &c. The deep red fuming acid,—sometimes called the "nitroso-nitric"—imparts oxygen, with still greater facility than pure nitric acid. It may be obtained, by passing nitric oxide into nitric acid. Part of the latter, yielding an atom of its oxygen, forms nitrous acid, which is absorbed by the remainder. $2NO_3+NO_2=3NO_4$.

236. Gold, platinum, iridium, rhodium, osmium, &c., resist the action of nitric acid: which, however, dissolves an alloy of gold and platinum. Gold may be separated from silver, by dissolving out the latter, with nitric acid—the process being termed "parting." But if more than a fourth of the alloy is gold, it will, to a certain extent, protect the silver from the action of the acid. In such a case, silver must be added. This is called "quartation,"* the gold being made to constitute a *fourth* part of the mass.

237. *Animal* matter, is decomposed, by nitric acid; and

* *Quartus*, the fourth. Lat.

it stains the skin and nails, a permanent yellow—the stain being rendered temporarily brighter by ammonia. It is sometimes used as a disinfectant: and a larger quantity of it may be inhaled, along with common air, in respiration, than of chlorine—which, also, as we shall find, is very efficient in destroying infection. Parliament gave £5,000 to the discoverer of the disinfecting power of nitric acid.

238. The facility with which this acid, even in combination, parts with oxygen, gives a considerable importance to some of the substances containing it: and may be exemplified, by throwing charcoal into red hot nitre. Detonation will occur, and most brilliant combustion will take place, carbonate of potash being produced. Nitre is a very necessary constituent of gunpowder. The latter, when of good quality, is changed, by the explosion—that ought to be neither too rapid, nor too slow—into gases which fill 1,000 times the space previously occupied by the powder. Many other substances are more powerful: but they explode so rapidly, that they would burst the gun, on account of their action not continuing long enough to overcome the inertia of the ball [mech. 6]. One part carbonate of potash (CO_2+KO) one part sulphur and three parts nitre, form a mixture which explodes so violently that, if placed in a metallic spoon and heated, the spoon will be indented—or even perforated. Nitrogen, carbonic acid, and sulphate of potash, are the results. $2(CO_2+KO)+3(NO_5+KO)+5S=3N+2CO_2+5(SO_3+KO)$. The quantity of gas is less than that produced by gunpowder: and its violent action, is caused by the speed with which ignition is communicated, through its entire mass. Rapidity of combustion, is due to the sulphur; the charcoal, furnishes the gas:—three parts nitre and one of charcoal, form a mixture which burns quickly, but without explosion: carbonate of potash is formed, carbonic acid, and nitrogen being evolved. $2(NO_5+KO)+5C=2(CO_2+KO)+3CO_2+2N$. More sulphur than is ordinarily used, would increase the strength of the powder; but would injure the fire-arms, by forming higher sulphurets of potassium—which part with a portion of their sulphur, without difficulty. Sulphur, changed to sulphurous acid, or having no element in the powder *with which it may* combine, would evidently be very in-

proper. Too much nitre also, would be mischievous: but it is not likely to be in excess—on account of its expense.

Nitrate of soda, being very deliquescent, cannot be substituted for nitrate of potash, in the manufacture of gunpowder.

239. Theoretically, gunpowder ought to contain one atom nitre, one atom sulphur, and either three or six atoms carbon: since these would be entirely converted into sulphuret of potassium, carbonic acid—or carbonic oxide—and nitrogen. It depends on the manufacturer, whether carbonic acid or carbonic oxide shall be one of the results. $(NO_5+KO)+S+3C=KS+3CO_2+N$: and $(NO_5+KO)+S+6C=KS+6CO+N$. If any carbonate of potash is formed, the effect of the powder is diminished; the increase of volume, produced by the explosion, not being so great.

240. The gases actually produced, during the combustion of gunpowder, were ascertained by Chevreul, and Gay Lussac, from specimens examined by them, to be

	Chevreul.	Gay Lussac.
Carbonic acid,	45·41	53·00
Nitrogen,	37·53	42·00
Carbonic oxide,	00·00	5·00
Nitric oxide,	8·10	
Carburetted hydrogen,	0·59	
A peculiar gas, containing carbon, hydrogen, and oxygen,	8 37	
	100·00	100·00

241. When rocks, earth, &c., are overturned by gunpowder, if the quantity is properly adjusted, the effect is produced so gently, that the resulting sulphuret of potassium, and the non-permanently elastic fluids have time to be condensed, and the permanent gases are cooled down, and partially absorbed—or they gradually escape: so that little noise or smoke, compared with the amount of powder, will be perceived. Similar causes diminish the noise, &c. of gunpowder, fired under water.

242. The flame perceived at the mouth of the gun, is due to the hot sulphuret of potassium and combustible gases, coming in contact with atmospheric air, and causing *a second* combustion—sulphate of potash, carbonic acid *and water*, being produced.

243. *Tests for nitric acid.*—We have no very good direct test for ascertaining the presence of nitric acid; since the neutral, and most of the basic nitrates, being soluble in water, do not afford precipitates. It may, however, be recognised, by evolving red fumes, when brought into contact with a metal. If the nitric acid is in combination, the red fumes are disengaged, on heating the solution containing it in a test tube, along with some copper filings and oil of vitriol. In both cases, the nitric oxide, liberated by the metal [220], is changed into hyponitrous acid by the oxygen of the atmosphere: and, in the latter, the sulphuric acid combines with the base of the nitrate. If hydrochloric acid is added to a liquid containing nitric acid, the mixture will dissolve gold. For hydrochloric and nitric acids will, as we shall find hereafter, produce nitrous acid, water, and chlorine—which dissolves the gold. $NO_5+HCl=NO_4+HO+Cl$. If the nitric acid is in combination, a chloride, also, will be obtained. $(NO_5+KO)+2HCl=NO+2HO+KCl+Cl$. This test is not, however, decisive; since the presence of chloric acid (ClO_5), &c., also, would cause the gold to be dissolved. If there is added to a fluid containing nitric acid, as much of the solution of indigo in sulphuric acid, as will make it of a faint light-blue colour, adding a few drops of sulphuric acid, and subsequently boiling the mixture, will bleach it, or, if the quantity of nitric acid is small, will render it yellow: for, the nitric liberated by the sulphuric acid, oxidizes the indigo. But other substances, particularly free chlorine, would produce the same effect. If a small crystal of green vitriol [protosulphate of iron (SO_3+FeO)] is placed in contact with a fluid containing nitric acid—after it has been mixed with one-fourth of its volume of strong sulphuric acid, and has been allowed to cool—the portion surrounding the crystal will become of a dark olive brown colour. Some of the iron is peroxidated by the nitric acid: and the resulting nitric oxide combines with a portion of the protosulphate [223], so as to form a compound, that gives the dark tint to the water, in which it is dissolved—but which is so unstable, that heat, or a slight agitation, causes it to disappear. Supposing the acid present to be in combination with potash, $8(SO_3+FeO)+$

$4SO_3+(NO_5+KO)=3(3SO_3+Fe_2O_3)+(SO_3+KO$
$2(SO_3+FeO)+NO_2$. Lastly, nitric acid gives a deep
colour, with a crystal of morphia.

244. AMMONIA:*—*symb.* NH_3; *equiv.* 17·02. I
never found, in nature, in the free or uncombined f
What is present in the atmosphere, and is absorbed by
and snow water [213], is probably united with carb
acid. It is found to have the odour of perspiration
night soil: which shows the principal sources whence
derived. The softness and peculiar feel of the hand, v
moistened with rain water, is due to the presence of
bonate of ammonia.

245. Ammonia cannot be formed synthetically, ex
when the gases which constitute it are in the nascent s
If, however, as much nitric acid is added to zinc, pl
in dilute sulphuric acid, as will cause the evolution of
to cease, water and nitric acid will be decomposed,
phate of zinc and sulphate of ammonia being prod
Iron may be used instead of zinc. Or, if 40 grs. iro
ings and 2 grs. hydrate of potash, carefully mixed in
tube, are heated to redness, the water united with the
ash will be decomposed, oxide of iron being formed
hydrogen liberated. Or, if 40 grs. iron filings and 2
nitre, carefully mixed in a test tube, are heated, oxi
iron will be formed, and nitrogen liberated. But, i
two experiments are made together, all the ingred
being mixed in the same test tube, and heated, the nitr
and hydrogen will unite and form ammonia: as will be
ceived by the smell, or a piece of reddened litmus
held above, which will become blue. The elements
unite in the *nascent* state. Ammonia may be conveni
obtained, by mixing, in a mortar, equal weights of sl
lime (CaO) and sal-ammoniac (NH_4Cl), then placin
mixture in a retort, and gently heating it. Chlori
calcium, ammonia, and water, are the results. NH_4
$CaO=CaCl+NH_3+HO$. It must be collected over
cury: and should be transmitted to the receiver thro
tube containing lime, or fused potash—to absorb any
which may be carried over with it.

* *So called* on account of one of its compounds being *near the* temple of Jupiter Ammon, in Lybia.

246. Ammonia, so obtained, is a colourless gas; of a penetrating odour, and an acrid taste. It is neither a supporter of combustion, nor inflammable—though a small jet of it will burn in oxygen. It is irrespirable, causing, when inhaled along with common air, bronchitis or inflammation of the mucous membrane of the air passages of the lungs. Hence, applied in fainting fits, or to counteract the effects of prussic acid, &c., it must be used with caution; and instances are known in which patients have died in such cases, from an over-dose of it. Its specific gravity is 0·59669:—100 cubic inches weigh 18·5044 grains. Water at 60°, absorbs more than 600 volumes of ammonia, with the evolution of great heat: but, if it is kept cold, it may be made to contain so much as 26·5 per cent. of that gas. Water holding it in solution is called "water of ammonia," or—incorrectly—"liquid ammonia." The apparatus, fig. 22 [page 41], may be employed in forming aqueous ammonia. Both that gas, and cyanogen, diminish the density of the water, with which they are combined: hence, the low specific gravity of their solutions is a proof of strength. Ammonia, associated with the elements of water, is an alkali; and from its volatility is termed the "volatile" alkali. It combines with the various acids, and hydracids: with sulphur, &c. No base has a smaller atomic weight.

247. Compounds of Ammonia.—*Carbonate of ammonia* (CO_2+NH_4O), may be obtained, by dissolving commercial sesquicarbonate of ammonia in four parts water, and adding one part strong water of ammonia. The solution of this salt should leave no residuum, on being evaporated. It is used by pastry cooks to give sponginess to their cakes: and passes off, during the baking, in vapour, rendering the bread porous.

248. *Nitrate of ammonia* (NO_5+NH_4O), may be formed, by neutralizing water of ammonia, or saturating a solution of carbonate of ammonia with nitric acid. The salt [216], may be obtained by evaporation.

249. *Sulphite of ammonia* (SO_2+NH_4O), may be made, by neutralizing water of ammonia with sulphurous acid.

250. *Sulphate of ammonia* (SO_3+NH_4O), may be obtained, by neutralizing water of ammonia with sulphuric acid.

251. *Oxalate of ammonia* ($C_2O_3+NH_4O$), may be made, by neutralizing water of ammonia with oxalic acid. It does not decompose, by keeping: and is therefore more convenient, as a re-agent, than oxalic acid.

252. *Sal-ammoniac* (NH_4Cl), is formed abundantly, from the carbonate and sulphate of ammonia, contained in soot. The former, is previously changed to a sulphate, by the addition of sulphate of lime: and the carbonate of lime, which results, is left behind, when the sulphate is removed, in solution. The sulphate of ammonia, being evaporated to dryness, is mixed with common salt: after which the sal-ammoniac and sulphate of soda, produced, are separated by subliming the former. Sal-ammoniac is procured, also, by the decomposition of horns, bones, and other substances, containing nitrogen. It may be obtained, as a re-agent, by purifying the sal-ammoniac of commerce, with two or three re-crystallizations.

253. *Hydrosulphuret of ammonia* (NH_4S+HS), may be made, by saturating a strong solution of ammonia with sulphuretted hydrogen, until the liquid ceases to give a precipitate with sulphate of magnesia. It is a colourless, volatile liquid, and contains, at first, an excess of sulphuretted hydrogen; but, on exposure to the air, it acquires a yellowish tinge; by the formation of a penta-sulphuret of ammonium (NH_4S_5), which will cause it, when mixed with acids, to deposit sulphur. Hydrosulphuret of ammonia, containing an excess of sulphur—obtained sometimes, by adding finely levigated sulphur—is frequently employed in testing. It may be known to have an excess, when it is of a yellowish colour.

254. *Tests for ammonia.*—Bichloride of platinum gives, with ammonia, a yellow crystalline precipitate ($NH_4Cl+PtCl_2$): and tartaric acid, in concentrated solutions, a crystalline bitartrate. An ammoniacal salt is detected with great certainty, by adding to the substance supposed to contain it, lime, or potash, and applying heat:—the ammonia which escapes will be perceived by its odour, and will restore the blue colour of reddened litmus paper, held over it.

255. There is some reason to believe that ammonia, like the other alkalies, is the oxide of a metal—which has been

termed *ammonium*, its symbol being NH_4. In such a case, what is ordinarily considered ammonia and water, will be oxide of ammonium:—$NH_3+HO=NH_4O$. Ammonia forms with mercury, under the action of the galvanic battery [183], an amalgam: but it is immediately re-produced, water being decomposed. This amalgam may be made, also, by dropping a grain of potassium dissolved in 100 grains of mercury, into a strong solution of sal-ammoniac. The mercury swells up, and the resulting amalgam is sufficiently permanent to be examined.

256. Some chemists have supposed that the proximate elements of ammonia are a substance termed *amidogene* (NH_2), and hydrogen. For, potassium, in dry gaseous ammonia, liberates hydrogen; and amidide of potassium, an olive-coloured body, remains behind. The third atom of hydrogen, therefore, is not so strongly combined as the others. It is likely that, in some cases—as, for instance, with certain metallic compounds, and organic acids—ammonia acts as amidide of hydrogen, and abandons an atom of hydrogen. Thus, with protochloride of mercury ($HgCl$), it forms amidide of mercury and hydrochloric acid. $NH_3+HgCl=HgNH_2+HCl$. Oxalate of ammonia ($C_2O_3+NH_4O$), when heated, forms oxamide ($C_2O_2+NH_2$) and two atoms of water. But it is probable that, in other cases, the amidide of hydrogen is associated with the elements of water, and acts as an alkali—forming an oxide of the metal ammonium.

It is supposed that hydrogen combines, in three proportions, with nitrogen.

257. Ter-Chloride of Azote:—*symb.* NCl_3; *equiv.* 120·43. It is obtained, by decomposing ammonia with chlorine. Ter-chloride of azote, and hydrochloric acid, are the results. $NH_3+Cl_6=NCl_3+3HCl$. It is a very dangerous substance; since its elements have so feeble an affinity, that they are separated by the least motion—a violent explosion being produced. Dulong, who discovered it, lost an eye and arm, during his experiments upon it.

258. Nitrogen forms, with iodine, likewise an explosive compound—not quite so violent, however, in its effects, as the ter-chloride: and, also, an analogous combination, with *bromine*.

259. CARBON:—*symb.* C.; *equiv.* 6. It is a very well known element; and constitutes, with small quantities of other bodies, coke and charcoal—the former being obtained, by igniting mineral coal, and the latter, wood, to a greater or less extent out of contact with the atmosphere. Coke, though apparently very soft, consists of crystalline plates so hard as actually to *cut* glass—any substance that is harder than it will *scratch* it. Great quantities of coke are manufactured from the refuse coal, of which about one million of tons was formerly burned each year at the mouth of the pit. Coal, in coking, loses one-fourth of its weight, but gains one-fourth in bulk. Wood, during the process of conversion into charcoal, loses about seventy-eight per cent. in weight. Theoretically, it should lose considerably less: but much of the carbon is necessarily carried off, in combination with hydrogen: and much is wasted by even the best methods of charring. Black lead—called also *plumbago* and *graphite*—is a compound of carbon and iron: and, sometimes, consists of carbon alone. Karsten's experiments leave no doubt that it is a peculiar form of carbon; and that the foreign substances, it contains, are merely accidental. It may be procured, artificially, by adding an excess of carbon, to iron in a state of fusion, and allowing it to cool:—some of the carbon which it dissolved when hot, will separate in the crystalline form. Lamp-black is almost entirely carbon. Ivory-black or animal charcoal contains the salts of the bones, which are burned to produce it. When these are heated in a close vessel, their gelatine is decomposed, carbonic acid, ammonia, and a fetid oil (Dippel's animal oil) being given off, and animal charcoal being left behind. Pure carbon may be obtained from this, by digesting it with dilute nitric acid, then washing it with water, and drying it at a proper heat. The diamond is carbon in a state of purity: and, as well as graphite, will burn in oxygen.

260. Carbon is a bad conductor of heat; but it transmits electricity freely. If oxygen is excluded, it is indestructible in the most intense fire. It absorbs gases in large quantities:—in making experiments, on this *subject, the* charcoal is to be strongly heated, and then *cooled* without excess of air. A cubic inch of box

charcoal, which acts the best, was found to absorb

	Cubic inches.		Cubic inches.
rogen, . .	1·75	Nitrous oxide, . .	40·00
ogen, . . .	7·50	Sulphuretted hydrogen,	55·00
gen, . . .	9·25	Sulphurous acid, .	65·00
onic acid, . .	35·00	Hydrochloric acid, .	85·00
iant gas, . .	35·00	Ammonia, . . .	90·00

arcoal, exposed to the air, becomes less inflammable, ains in heating power. The cause of this is not n.

. Tainted flesh, or bad water, may be purified with oal:—casks are charred inside, on account of this ty. Its antiseptic qualities were known very early: driven down, for the foundations of bridges, more 2,000 years ago, are found charred. Animal char- boiled with ale, beer, port wine, &c., will render them less:—ordinary charcoal would not produce the same

When ale is decolourized by filtration through l charcoal, the bitter principle also is removed; which nts its being applied to the purpose.

. Carbon forms, with oxygen, carbonic oxide (CO: carbonic acid (CO_2:22), and oxalic acid (C_2O_3:36). hydrogen, olefiant gas (C_2H_2:14): light carburetted gen (CH_2:8): and a variety of compounds, the most tant of which will be noticed at the proper times. It nes, also, with many of the other elements.

. Compounds of Carbon. Carbonic Oxide; CO; *equiv.* 14. It is procured, by mixing pounded limestone, or marble (CO_2+CaO), with iron filings, plying a strong heat. Half the oxygen goes to the lime, oxide of iron, and carbonic oxide, being the . $(CO_2+CaO)+Fe=CaO+FeO+CO$. Charcoal answer in place of the iron: there would then be oms of carbonic oxide, and one of lime. (CO_2+CaO) $=CaO+2CO$. It may be obtained, likewise, by di- g either binoxalate of potash $[(C_2O_3+KO)+(C_2O_3$ $)]$, or oxalic acid (C_2O_3+HO), with strong sulphu- d. In the former case, the sulphuric acid, taking he potash and basic water, liberates the oxalic acid; *not being* able to exist uncombined, is immediately

decomposed into a mixture of carbonic acid and earb
oxide, bisulphate of potash being formed. $[(C_2O_3+$
$+C_2O_3+HO)]+2SO_3=[(SO_3+KO)+(SO_3+HO$
$2CO_2+2CO$. In the latter, the same mixed gas i
berated, by the oxalic acid being deprived of its
water. $(C_2O_3+HO)+SO_3=(SO_3+HO)+CO_2+CO$
the mixed gas is transmitted, from the retort, to a v
containing a solution of caustic potash, the carbonic
will be absorbed, carbonate of potash being formed:
pure carbonic oxide will pass out of the apparatus.

264. Carbonic oxide is without colour, taste, or sr
it burns with a bluish flame—which [162] might be
pected, as the affinity which makes it combine witl
atom of oxygen, to form carbonic acid, is not very str
It supports neither combustion or respiration—produ
narcotic effects. Its specific gravity is 0·9727:—100
inches, weigh 30·1651 grains.

265. Carbonic oxide is often produced in furnaces
stead of carbonic acid, from an insufficient supply
mospheric air. It is not detected, as it escapes; bu
waste of fuel may nevertheless be very great. It is fo
by decomposition of carbonic acid, as it passes over th
hot coals, an additional quantity of carbon being disso
In such a case the fuel gives considerably less heat
should be expected from it. The carbonic acid is nev
decomposed.

266. Carbonic Acid:—*symb.* CO_2; *equiv.* 22. I
known long before its real nature was discovered—
considered by the ancients as a pestilential vapour,
termed by them "spiritus lethalis."* Some of the
eminent alchymists, believed it to be a particular
and called it "spiritus sylvestris."† Boerhave, thoug
was a form of atmospheric air. Black proved, in
that it was a distinct substance, and obtained it:
called it "fixed air,"‡ a name given to it before the e
riments of Cavendish, and others, showed that it w
acid. Lavoisier, accurately determined its compositi

* A deadly air. *Lat.* † Forest air. *Lat.*

‡ *It* was termed *fixed* or *fixable* air, from being found "fixe
limestone, &c. This name had been given to other gases,
were found to be contained in solids, &c.

and it then obtained the names of "mephitic,"* and "aerial acid," the "acid of charcoal," and finally carbonic acid. The discovery of the true constitution of this gas, forms a most important era in chemistry. Before the researches of Black, the action of lime on the alkaline carbonates, which, as we shall find, is now so evident, was totally misunderstood. The lime was supposed, during the process of burning, to take from the fire, some element which rendered it caustic:† and which, being imparted to what are now known to be carbonates of the alkalies, transferred the causticity to them. In his early experiments, Black endeavoured to obtain what was thus supposed to pass from the fire to the lime, and from the lime to the potash, &c.

267. Carbonic acid is found, most abundantly, in nature. It constitutes a large part, by weight, of limestone, marble, chalk, &c.; and is the chief product of combustion and respiration. It may be procured from any of the carbonates, by acting on them with an acid. When carbonate of lime—marble, for example, which is nearly pure carbonate—is employed, it is better to use hydrochloric acid which forms a soluble, than sulphuric which forms an insoluble compound. With carbonate of lime and sulphuric acid, the results are carbonic acid and sulphate of lime. $(CO_2+CaO)+SO_3=(SO_3+CaO)+CO_2$. When hydrochloric acid is used, chloride of calcium, carbonic acid and water are produced. $(CO_2+CaO)+HCl=ClCa+CO_2+HO$.

268. Carbonic acid is a colourless gas; it has a rather sharp taste, and a very pungent smell. It is neither a combustible, nor a supporter of combustion or respiration. If the nose is held incautiously over a vessel from which it is escaping, it may cause coughing and sneezing—and even giddiness, and weakness. The glottis closes, spasmodically, against it. It is the "choke-damp"‡ of the miners: but if taken into the lungs diluted with common air, it is narcotic. Persons are frequently suffocated by it, in breweries, distilleries, lime-kilns, &c.; also, those who sleep in rooms without chimneys, while fire is burning. A grotto, near Naples, is called the "Grotto del cane,"§ from the

* *Mephitis*, an ill odour. *Lat.*
† *Kauo*, I burn. *Gr.*
‡ Dampf, vapour. *Ger.*
§ "Dog's grotto." Ital.

effect it produces on these animals. It contains a
of carbonic acid, which rises to the height of about
inches, and then flows over the entrance, into the la
low. A human being experiences no inconvenience
it, since his head is far above the level of the gas. T
ing the dog, which has been affected by the carbonic
into the lake, recovers it—provided the remedy is a
sufficiently soon. Generally speaking, there is no
from carbonic acid, where a candle will burn. This
ever, is not always true; and it would be infatuati
venture where a candle is extinguished. It is not
the want of oxygen, which causes the candle to go ou
carbonic acid exercises a positive influence, since it w
burn in an atmosphere containing one-fifth of its vol
this gas. Water absorbs, under the ordinary atmos
pressure, an equal volume of it—which is given out
by boiling, or reducing the pressure. Its presen
water, causes that fluid to sparkle, when poured fro
glass to another; and the want of it, in recently
water, makes the latter insipid. Under increased pr
water absorbs still larger quantities—dependent on th
sure. Though poisonous, when taken into the lung
harmless, or even advantageous, as a sedative, when
into the stomach in moderate quantities. Soda-w
nothing more than common water, into which ca
acid has been forced, under great pressure, and whic
tains, also, a small quantity of potash, soda, &c. Th
properties of this gas may be proved, by its reddeni
mus paper: the colour of which, however, returns,
the acid volatilizes. Its specific gravity is 1·511
cubic inches, weigh 46·8587 grains. That it is
heavier than common air, may be very strikingly
trated, by pouring it from one glass jar into anothe
taining atmospheric air, and then over a candle—w
will immediately extinguish. The spectator sees n
pass from one jar to the other; and yet the air with
latter has put out the candle—though what it contai
first, would not produce that effect.

269. Carbonic acid, at a temperature of 0°, is li
by a pressure of thirty-six atmospheres; and wh
pressure is suddenly removed, congeals by the cold

m its own evaporation. Liquid carbonic acid, is a pid and colourless fluid. Its specific gravity at 32°, is 83. It distils rapidly at a temperature between 0° and °. It is insoluble in water, or the fat oils; but dissolves dily in alcohol, ether, turpentine, &c. Solid carbonic id, resembles asbestos. Being a bad conductor of heat, does not evaporate rapidly, nor feel very cold. It dis-ves in alcohol, and ether. The evaporation of its ethe-l solution, produces the lowest temperature known [heat 8.] Faraday availed himself of the cold obtained by it in conjunction with great pressure—to liquefy, and even lidify, several of the gases.

270. Carbonic acid is a powerful agent, in the disinte-ation of rocks. Even water containing it corrodes them: ice [195] it dissolves carbonate of lime. In this way, *alactites* and *stalagmites* are formed in limestone ca-rns. The rain water, holding carbonic acid in solution, ickles down through their roofs, and dissolves the carbo-te in its passage: and, as it hangs in drops, the carbonic id passes off, leaving carbonate of lime in the solid state which produces those beautiful, and often fantastic pen-nts, called "stalactites." When the water drops on the or of the cave, the carbonate of lime, precipitated in the me way, forms "stalagmites." The trickling of rain ater, through the arches of bridges, vaults, &c., gives rise similar effects, but generally on a small scale. Carbonic id dissolves carbonate of lead (CO_2+PbO): which, some-nes, causes water, contained in leaden cisterns, or pass-g through leaden pipes, to possess very deleterious quali-es. Carbonate of lead is, in these cases, formed by some the oxygen, and carbonic acid, contained in the water, d is dissolved by another portion of the acid: the lead ould be protected by minute quantities of the salts, ge-rally found in natural water. Hence, the cisterns, &c., hich are used for rain, or any almost pure water, and the vers of others that are moistened by what has evaporated and has, therefore, left behind, the solid substances, it riginally held in solution—are most affected in this way. may be proved, that the atmosphere contains carbonic id, by passing a quantity of common air, through lime ater. Carbonate of lime (CO_2+CaO) will be, at first,

precipitated, and will, afterwards, be redissolved, by excess of the acid.

271. The evolution of carbonic acid is ingeniously used, to separate the fibres of flax, so as to change it instantaneously into a substance resembling cotton, and applicable to all the purposes for which the latter is used. The flax having been boiled for about six hours, in a weak solution of caustic potash, which removes the resinous and oily substances of the plant, is placed in a solution of bicarbonate, or sesquicarbonate of soda, for three or four hours: and, then, in a weak solution of sulphuric, or other acid. The expansive force of the disengaged carbonic acid, instantaneously splits the fibres into a vast number of filaments which, under the microscope, appear like raw cotton.

272. Gay Lussac, has shown that plants decompose some of the carbonic acid of the atmosphere; since, in France, there are large forests, in siliceous soils which contain no organic matter:—their entire carbon must, therefore, be derived from the atmosphere. We shall find, that plants absorb carbonic acid, during the day: and decompose some of it, oxygen being evolved—particularly in sunshine. Thus, the injury done to the atmosphere, by the animal, is repaired by the vegetable kingdom. Carbonic acid is evolved by living plants, at night: and by those in a state of decomposition, at all times.

Carbonic acid, is driven off from its compounds with the alkaline earths, by heat: but not from its alkaline compounds.

Oxalic acid will be examined among the vegetable acids.

273. Olefiant* Gas:—*symb.* C_2H_2: *equiv.* 14. It is so called, because, with chlorine, it forms a fluid resembling oil, in appearance: and is obtained, by mixing in a large retort, one part, by weight, of very strong alcohol, with four parts oil of vitriol, and applying heat. An equal weight of the oil of vitriol, would produce sulphuric ether.

274. Olefiant gas, has neither colour, taste, nor smell. It is inflammable, but does not support combustion, nor respiration. Its specific gravity is 0·9746:—100 cubic inches, weigh 30·224 grains. It is highly important, on account of being the most valuable constituent of gases

* *Oleum*, oil; and *fio*, I am made. Lat.

used for illumination. It is also very interesting from being, most probably, the *radical* of a great number of substances, to which we shall advert hereafter.

275. Light Carburetted Hydrogen, or Marsh Gas:—*symb.* CH_2; *equiv.* 8. It can be obtained—along with carbonic acid, however—by stirring up stagnant pools. It is evolved, also, by heating well mixed equal parts of acetate of potash ($C_4H_3O_3+KO$), and caustic potash. Water is decomposed, carbonic acid, and light carburetted hydrogen being given off. The carbonic acid unites with the potash: and the light carburetted hydrogen may be collected, over water. $(C_4H_3O_3+KO)+KO+HO = 2(CO_2+KO)+2CH_2$.

276. This gas has neither colour, taste, nor smell. It is highly inflammable—water and carbonic acid being the result of its combustion; it is a component of all the gases, used for illumination. It does not support either combustion, or respiration. Its specific gravity is 0·557:—100 cubic inches, weigh 17·2735 grains. It forms a highly explosive mixture, with common air: and is termed "the fire damp," by miners. It is evolved abundantly, in coal mines: and is produced, whenever vegetable matter is decomposed under water. The lignine ($C_{12}H_8O_8$)—or woody fibre, forms, with four atoms of water, six atoms of the carbonic acid, and six atoms of this gas. $C_{12}H_8O_8+4HO = 6CO_2+6CH_2$. Coal being the remains of enormous accumulations of wood, large quantities of marsh gas were evolved by it, and were liquefied, by the immense pressure;—but, when the latter is removed, it assumes the gaseous form, and escapes into the mine. Davy's lamp [187], prevents the danger, arising from its mixture with common air.

277. Gases for Illumination. Coal Gas.—Dr. Clayton observed, in the year 1664, that combustible illuminating gas was produced, during the decomposition of coal by heat. Lord Dundonald, to amuse himself, built some coke furnaces in 1786, collected the gas, and burned it in tubes. The factory of Bolton and Watt, was lighted with gas in 1798. London was first lighted with it in 1812; and Paris, in 1815. The Chinese, though they did not manufacture *this gas*, employed it for the purpose of light-

ing, and heating, long before it was thus used by Europeans. Their salt borers frequently pierce beds of coal, and convey the inflammable gas, in pipes, to the salt works, to light them, and to evaporate the salt, &c.;—when there is more gas than is necessary, they burn it outside the works, in their streets, &c.

278. Coal gas is obtained from bituminous coal:—and the apparatus used, though varied in its details, according to circumstances, is always the same in principle. In the production of gas for the illumination of cities, the works are of immense extent, and the quantity produced is very great. The coal is placed in cast iron retorts A, B, D, &c., fig. 25, and heated to a cherry red. If the retorts are

FIG. 25.

at first cold, the tar—which is the chief product, at a temperature below redness—is merely volatilized; but little gas, which is almost entirely hydrogen and atmospheric air, being obtained. At a temperature below 400°, the volatile constituents of the coal pass off, chiefly as naptha or liquid hydrocarbons: but a cherry red, or somewhat higher heat, decomposes these volatile constituents, almost entirely, into gases, with the production of but little naptha, or tar. Towards the end of the process, if it is continued beyond a certain time, almost pure hydrogen is evolved: the hydrocarbons being decomposed, in passing

over the intensely hot coke, &c. If the coals employed in making gas are wet, the outer portion of what is in the retort becomes red hot, before the water in the interior is expelled. This water, being then vaporized, is decomposed by the red-hot coke, hydrogen, and carbonic oxide being evolved, which dilute the coal gas and lessen its illuminating power: as well as carbonic acid, which neutralizes the lime in the purifier, and thus wastes it. Also, since the latent heat of steam is [heat, 81] 966°, a great quantity of caloric must be absorbed, in vaporizing the water: and thus a temperature favourable to the production of tar, or naptha, must be the result.

Too high, and long-continued, a heat not only decomposes olefiant gas, depriving it of its carbon, but resolves the protosulphuret of iron—which was formed from the pyrites, which all coal contains—by some of its sulphur having united with hydrogen, into metallic iron, which remains in the coke, and bisulphuret of carbon, which mixes with the gas. This bisulphuret, which cannot be banished, forms sulphuric acid, when the gas is burned. And, though the quantity of this acid which is thus produced is small, it is found quite sufficient to destroy the paper, and binding, of books in public libraries, and corrode articles in metal. Iron retorts, are rapidly destroyed by the action of the atmospheric air, at a high temperature, by the sulphur present in the coal, and by the carbon—which, combining with the iron, forms graphite. Hence, those which are now very commonly employed, are made of earthenware.

279. Coal gas is a complicated compound. It contains ammonia [244], cyanogen (C_2N or Cy.), sulpho-cyanogen ($Cy\ S_2$), sulphur, sulphurous acid (SO_2), carbonate oxide [263], carbonic acid [266], hydrochloric acid (HCl), olefiant gas [273], light carburetted hydrogen [275], etherine (C_4H_4), bicarburetted hydrogen (C_2H) sulphuretted hydrogen (SH), bisulphuret of carbon (CS_2), water, and very frequently hydrogen. Napthaline (H_4C_{10}), and naptha (H_3C_6), are present in the form of vapour: and give to coal gas its peculiar smell. The carbonic oxide, and hydrogen, are due to the decomposition of the vapour of water, as it passes over the ignited coke. The nitrogen of

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the coal, assumes the form of cyanogen, and ammonia:—any, in the free state, is the residue of atmospheric air, which was in the retort when the coal was introduced. Coal contains the one-five-thousandth of its weight of ammonia; and coal gas, the one-three-hundredth of its volume. Some of the ammonia, is in combination with sulpho-cyanogen, &c. The sulphuretted hydrogen, and sulphurous acid, are derived from iron pyrites (FeS_2), in the coal. The former gives but little light: and, during combustion, forms sulphurous acid, and water. The smoke from a coal fire has, from containing it, sometimes produced an inconvenient effect, on persons using a salt of bismuth as a cosmetic: having been known to render the face almost black, to the astonishment of those who did not know the reason of such a change. Sulphuret of bismuth, was produced, in these cases. Sulphuret of carbon, and sulpho-cyanogen would, in burning, produce sulphurous acid. Ammonia, would form nitric acid and water: cyanogen, carbonic acid, and nitrogen. If impure coal gas is passed over protoxide of iron, or peroxide—since the latter is changed into protoxide, by the sulphuretted hydrogen present—cyanogen will be absorbed, and a quantity of Prussian blue, greater in value than the coal whence it was obtained, may result.

280. In the manufacture of coal gas, the management of the heat is very important; the higher it is, the greater the quantity, but the worse the quality of the product. For, the olefiant gas, to which its brilliancy is principally due, is decomposed into light carburetted hydrogen, and carbon—which is deposited. Or even, if the temperature be very high, hydrogen is evolved uncombined with carbon: and then, the gas obtained, gives great heat, and but little light [190]. The higher the specific gravity of coal gas, the larger the quantity of carbon it contains, and the greater its illuminating power.

281. The manufacture of coke for smelting purposes, locomotives, &c., requires conditions incompatible with the economical production of illuminating gases [steam 81]. Hence, in manufacturing it on the larger scale, they are *allowed* to be consumed, to escape, or to contribute by *their combustion* to the production of the coke. The ob-

ject of the manufacturer is, to obtain the coke as dense, and in as large masses as possible. This cannot be effected with large coal [259]—which must therefore, when employed, even be broken up artificially. The best coke is obtained from large masses of coal; and ten or fifteen tons are sometimes placed in a single oven. A gas retort, will be charged with about one and a half cwt. The air is allowed, with certain precautions, to have access to the coal, during the process of coking. Both the amount and density, are improved, by the deposition of carbon from the decomposed hydrocarbons:—this, however [280], deteriorates the quality of the gas. In the best methods of manufacture, after the process is completed, air is excluded from the coke: which being kept for some time in the heated state, contracts in bulk, and increases in density.

282. The coal gas is first passed through tar, in the pipe PT, fig. 25: which causes tar and bitumen to be condensed, and deposited. It is then cooled, by transmission through pipes surrounded with water; and is next passed through cream of lime—a mixture of lime and water, kept agitated by machinery—which removes the carbonic acid, by forming carbonate of lime (CO_2+CaO), and the sulphuretted hydrogen, by forming sulphuret of calcium (CaS), and [254] decomposes the ammoniacal salts, the ammonia being absorbed by the water.

Trellis work—or sieves—covered with moss, well mixed with moist lime, are now very often used, instead of cream of lime; as the gas is, thus, brought more fully into contact with the lime. When cream of lime is employed, there is, also, a considerable water pressure; and the force necessary to overcome it, causes the gas more readily to leak, and more rapidly to deposit carbon in the retort.

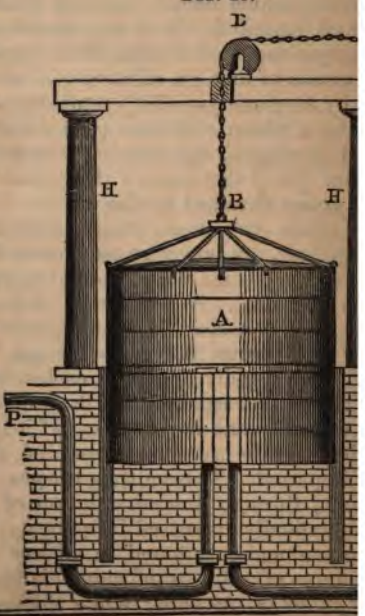
283. The perfect separation of the ammonia, is a matter of equal difficulty and importance. If it is removed by an acid, unless certain precautions are used, the illuminating power is impaired. Transmitting the gas, before it arrives at the lime, through a weak solution of sulphuric acid, which is gradually increased in quantity, as it combines with the ammonia, is found to answer extremely well. Eighty ounces of sulphate of ammonia are then obtained, for every *gallon of the* fluid; while the ordinary ammoni-

acal liquor affords only 14 ounces. Besides s
cocks, &c., the separation of all the ammonia is s
crease the illuminating power, five per cent. N
though it increases the brilliancy of the gas, is
on account of forming crystalline deposits in t
Various other contrivances are used, for removin
ties. If coal gas contains ammonia, it will restore
litmus paper: if sulphuretted hydrogen, it wil
paper dipped in a solution of acetate of lead: if
acid, it will render lime water turbid: and, in an
cases, it is unfit for use.

The amount of gas produced, varies with th
coal. 100 cubic feet of the latter, give about 19,
feet of the former.

284. When the gas is purified, it is transmi
gas-holder or reservoir—improperly called a *gasometer*. It consists of a cylindrical vessel A, fig. 26, made of wrought-iron plates, riveted together, so as to be air-tight. The open end is immersed in an annular cavity, filled with water, which—to prevent evaporation—is covered with a layer of tar. *A, is so balanced, by a*

FIG. 26.



counterpoise W, that it is easily raised by the gas:—and the weight it loses, when it sinks into the water, is compensated for, by the additional quantity of chain which passes down from the pulleys. The gas enters by the pipe P, and is brought to the mains by the pipe T, which is of lead, iron, &c.: the pressure which forces it out, being regulated by the amount of the counterpoise W. It has been found that when copper is used for the purpose, a pulverulent substance, liable to spontaneous combustion, is formed by combination of the metal with the elements of the gas.

285. The quantity of gas, consumed by individuals, &c., is now, very generally, registered by a *gas meter*—the principle of which may be understood from fig. 27. The gas enters by a pipe under E, and, by its buoyancy, causes the partitions—indicated by thick lines, and forming separate chambers, of known capacity—to revolve on an axis. As each chamber is filled, it moves round, and communicates with that portion of the drum which is above the water. The gas is conveyed, by the pipe N, to the burners. The axle, in revolving, communicates motion to a train of wheels and pinions, having, externally, dials and indices, which mark, respectively, hundreds, thousands, &c., of cubic feet. Each pinion, moves a wheel having ten times as many teeth as it has leaves. Ten revolutions, therefore, of one wheel [mech. 198], correspond with one of the next. Neither the gas company, nor the consumer, can alter the indication—which must be accurate, if the proper water level is maintained. There are other kinds of gas meter, some of them requiring no water.

FIG. 27.

286. Since the illuminating power of a gas, depends on the quantity of carbon united with the hydrogen, various plans have been devised, to saturate inferior gas with naptha—a substance extremely rich in carbon, and one of the products obtained by the destructive distillation of coal. This is effected, by passing the gas through the naptha; *or otherwise bringing* the two substances into contact. If

hydrogen, or the bad gas which may be obtained at the end of the distillation, is passed over the coal in the retort at the commencement of the process, not only will the gas dissolve carbon, and become excellent for illumination, but the hydrogen will prevent the hydrocarbons from being decomposed, and injuring the retort by the deposition of solid carbon: and will hinder light carburetted hydrogen from being formed, by abstraction of the carbon—to the diminution of the illuminating power. If gas, obtained by decomposing water with red-hot carbon is employed, the hydrocarbons will be destroyed, unless the vapour of water present is condensed. Hydrogen, therefore, and watery vapour, have opposite effects on these substances. If naptha is mixed with an equal quantity of water, and distilled, the resulting vapour being sent through a perforated nozzle, and set on fire, the flame will have great heat. The water is not decomposed, but merely serves, by expanding the vapour of the naptha, to bring it in contact with a larger quantity of atmospheric air, and cause it to burn without smoke. Napthalized gas, has the advantage of evolving less heat, during combustion: the quantity which it gives out—the illuminating power remaining the same—being, to that evolved by ordinary coal gas, as three is to four; and the light, which results, more closely resembles that of the sun. If coal gas is passed through alcohol, its illuminating power is almost entirely destroyed: but the alcohol will burn with a bright white flame, and will be rendered milky by water. Bromine has the property of removing from coal gas all the vapours which cause its luminosity. But as these vapours are of exceedingly various composition, their weight must be taken into account, when the luminous power of the gas is examined.

287. Oil Gas, is obtained, by dropping fish oil, and substances not fit for lamps, on iron, coke, or bricks, raised to a high temperature. It gives twice as much light as coal gas: having a larger quantity of olefiant gas—and no sulphuretted hydrogen. It does not require to be purified with lime. One cubic foot of oil, produces from six to seven hundred cubic feet of gas: which is equivalent to *from 90 to 96* per cent., by weight. Oil gas, has nearly *the same* density as atmospheric air.

A common candle, may be considered as an oil gas apparatus, on a small scale. The liquid tallow, drawn up by capillary attraction into the ignited part of the wick, affords the gas: which, being inflamed as fast as produced, causes the flame. If one extremity of a tube is introduced into the side of the flame, gas will ascend through it, and may be set on fire as it issues from the other extremity.

288. When resin is used for the production of gas, it is necessary to render it fluid, before submitting it to destructive distillation. For this purpose, oil of tar, &c., is employed. From 14 to 23 cubic feet of gas are obtained, by the destructive distillation of one pound of resin.

The hydrocarbons produced by the distillation of oils, fats, &c., are preserved by hydrogen [286], in the same way as those derived from coal.

The goodness of illuminating gas, is diminished by its being kept: and that of coal gas, more rapidly than that of oil gas.

289. To obviate the necessity of using pipes and other expensive apparatus, ordinarily required, various plans have been proposed, for the application of *portable* gas to the purposes of illumination. The first means devised, was the compression of a considerable quantity, into a small but strong receiver, attached to, and forming a part of the lamp, &c. This method, however, is attended with several disadvantages. Vessels of great strength are necessary, on account of the force of compressed gas—often considerably increased, by unavoidable changes of temperature. Moreover, the carbo-hydrogens, contained in illuminating gases, have their illuminating power greatly diminished by compression: since, a liquid, containing a valuable part of the constituents of oil gas—which is the most proper for the purpose—and consisting of three different substances, triyle (C_3H_3), ditriyle (C_2H_4), and another hydro-carbon (C_2H_3), separates. The danger of explosion, and the difficulty of obtaining a uniform flow of gas, with the constantly diminishing pressure, are other inconveniences.

Portable uncompressed gas has also been tried: but has not been much used.

CHAPTER III.

Sulphur, 290.—Compounds of Sulphur, 292.—Hyposulphurous Acid, 293.—Sulphurous Acid, 294.—Sulphuric Acid, 298.—Sulphuretted Hydrogen, 311.—Selenium, 316.—Phosphorus, 319.—Compounds of Phosphorus. Phosphorous Acid, 323.—Phosphoric Acid, 324.—Phosphuretted Hydrogen, 325.—Chlorine, 328.—Compounds of Chlorine. Hypochlorous Acid. Bleaching Salts, &c., 339.—Chlorous Acid, 346.—Perchlorous Acid, 347.—Chloric Acid, 349.—Hydrochloric Acid, 350.—Aqua Regia, 358.—Iodine, 359.—Bromine, 364.—Fluorine, 368.—Compounds of Fluorine. Hydrofluoric Acid, 370.—Silicon, 373.—Compounds of Silicon. Silex, 376.—Manufacture of Porcelain, 380.—Manufacture of Glass, 387.—Soluble Glass, 411.—Fluoride of Silicon, 416.—Boron, 421.—Compounds of Boron, 424.

290. SULPHUR:—*symb.* S; *equiv.* 16. It is found, principally, in the neighbourhood of volcanoes; and is obtained, also, in large quantities, combined with metals, &c. The best sulphur is brought from Sicily. Its chief properties are well known:—it is a non-conductor of heat, and of electricity; it melts at 226°, takes fire at 300°, begins to be thick and of a reddish colour at 320°, becomes somewhat liquid again at 482°, and is completely so at 601°: it then sublimes, and forms "flowers" of sulphur. If, at a temperature of 400°, it is suddenly immersed in cold water, it forms a soft, transparent, elastic mass; but it gradually changes to its ordinary state. It may be shown that sulphur crystallizes when cooling, by melting a tolerably large quantity, breaking the crust on its surface, before the mass is quite cold, and pouring out the part which is still liquid:—the internal portion, will then present a crystalline appearance. Its specific gravity, is 1·98. It dissolves in the oils; also, in caustic potash, cream of lime, &c., producing new compounds.

291. Sulphur forms, with oxygen, hyposulphurous acid (S_2O_2; *48*); sulphurous acid (SO_2; 32); a group consisting of hyposulphuric or—as it has been termed by Sir R.

Kane—deuto-thionic acid (S_2O_5; 72), trito-thionic acid (S_3O_5; 88), tetra-thionic acid (S_4O_5; 104), penta-thionic acid (S_5O_5; 120); also, sulphuric acid (SO_3; 40); and two other compounds, not as yet well known. It forms, with hydrogen, sulphuretted hydrogen (HS; 17); and bi-sulphuretted hydrogen (HS_2; 33). It combines, likewise, with carbon, &c.

292. Compounds of Sulphur.—The compounds of sulphur, very much resemble those of oxygen: for, the sulphurets are extremely like oxides; and sulphur forms sulphur salts, as oxygen forms oxy-salts—being, at the same time, the acidifying principle, and the element which, in the base of an oxy-salt, holds the place of oxygen. Thus, sulphur and arsenic form *sulpharsenious* acid: which, combining with the sulphuret of lead, forms sulpharsenite of lead.

The resemblance is very clearly illustrated, by the following—

Sulphocarbonic acid is	CS_2
Carbonic acid	CO_2
Sulphocarbonate of potassium . .	CS_2+KS.
Carbonate of potash	CO_2+KO.
Sulpharsenic acid	AsS_5.
Arsenic acid	AsO_5.
Sulpharseniate of potash . . .	AsS_5+KS.
Arseniate of potash	AsO_5+KO.

293. Hyposulphurous Acid:—*symb.* S_2O_2; *equiv.* 48. It is interesting, chiefly on account of hyposulphite of soda (S_2O_2+NaO), one of its compounds, being used in the daguerreotype process [opt. 123]. It may be obtained, by adding to one of its salts a stronger acid. Or—which is more convenient—bringing sulphurous acid (SO_2) and sulphuretted hydrogen (SH) into contact, under water. $4SO_2+2SH=3S_2O_2+2HO$. The water becomes exceedingly sour; but, after a while, the acid is decomposed, sulphurous acid being formed, and sulphur precipitated.

294. Sulphurous Acid:—*symb.* SO_2; *equiv.* 32. It is formed, when sulphur is burned in atmospheric air, or in dry oxygen; also when sulphuric acid (SO_3) is deprived of an atom of its oxygen, by being boiled with a metal. *It is very conveniently* procured, by heating together chirpe

of wood and sulphuric acid. And it may be obtained, in the liquid form, by passing the gas through a mixture of ice and salt, and collecting the result in a small tube closed at one end, and immersed in a freezing mixture.

295. Sulphurous acid, is a colourless gas, having a very pungent odour. Its specific gravity, is 2·21 :—100 cubic inches, weigh 68·5359 grains. At 0° Fahrenheit, it is a liquid, which is heavier than water, and boils at 14°. It is neither inflammable, nor a supporter of combustion :—and has a very suffocating effect, when breathed. It destroys vegetable colours : sometimes, first reddening them. But the colour gradually returns, on account of the escape of the sulphurous acid, from the colourless compounds it had formed with the colouring matter : and it may be restored, at once, by the action of an alkali, or of a stronger acid—sulphurous acid being given off. Its power of removing vegetable colours, may be illustrated by placing a red rose in the fumes of burning sulphur ; the colour will vanish, but will be brought back by washing in dilute sulphuric acid. Water, absorbs 37 volumes of sulphuric acid: and, has, then, to a very high degree, the properties of the gas. The solution, if boiled, gives out the sulphurous acid ; and, if kept, absorbs oxygen—sulphuric acid being formed. This gas is absorbed, still more abundantly by alcohol. It is a very feeble acid : being displaced from its combinations, by all others, except the carbonic, and hydrocyanic.

296. Many of the properties of sulphurous acid, are due to its affinity for oxygen. It stops fermentation, by absorbing that element :—hence, sulphur matches, are sometimes lighted over the bung-holes of casks, containing cider. It bleaches wool, or silk, by taking oxygen from the colouring matter ; and is used, with these substances, instead of chlorine—which would be very injurious, if employed to decolourize them. It reduces gold, silver, or mercury, when in the form of salts. Thus, ter-chloride of gold ($AuCl_3$) sulphurous acid and water, produce sulphuric acid (SO_3) hydrochloric acid (HCl) and metallic gold. $AuCl_3 + 3SO_2 + 3HO = 3SO_3 + 3HCl + Au$.

Peroxide of iron (Fe_2O_3), in similar circumstances, gives *only one-third* of its oxygen to the sulphurous acid : and *black oxide* of copper (CuO), but one-half.

297. The salts of sulphurous acid, produce the same deoxidizing effects; and all of them, that are soluble, have an alkaline reaction.

298. Sulphuric Acid:—*symb.* SO_3; *equiv.* 40. It was discovered by Basil Valentine, an alchymist, about the end of the fifteenth century: and is found abundantly in nature—combined with lime, &c.

Absolute sulphuric acid—or that which contains no water, and is therefore termed "anhydrous"—could not be procured, until a comparatively recent period. It is obtained, by expelling the acid from protosulphate of iron ($SO_3+FeO+7HO$), by a red heat. The crystals lose six atoms of their water, before the salt is decomposed: and the seventh, when decomposition commences. A red heat drives off the sulphuric acid, which, if the sulphate was quite dry, resolves itself spontaneously into sulphurous acid and oxygen: otherwise, sulphuric acid and water (probably $2SO_3+HO$) distil over in combination, as a thick, oily, dark coloured liquid, having a specific gravity of about 1·9. One-half of the sulphuric acid is, at the same time, decomposed, to peroxidate the iron, sulphurous acid being evolved. $4(SO_3+FeO)+HO=(2SO_3+HO)+2SO_2+2Fe_2O_3$. This oily liquid is received in a vessel, cooled externally: and is the fuming sulphuric acid, known as "German oil of vitriol."* When heated, it resolves itself into common oil of vitriol (SO_3+HO) and absolute acid (SO_3). The latter, being very volatile, distils over in colourless vapours: and, if received in a dry vessel, which is cooled by a freezing mixture, it condenses into tough, and elastic, white silky fibres.

299. Solid absolute sulphuric acid, has a specific gravity of 2·766. It melts at 77°; and boils at a temperature but little higher. Thrown into water, it hisses like red-hot iron. Its combination with dry barytes, lime, or magnesia, is accompanied by brilliant combustion.

The absolute acid forms several compounds with water; and mixes with it, in all proportions.

* *Vitrum*, glass. *Lat.* The sulphates were formerly called "vitriols," from their glassy appearance; and their acid was termed "vitriolic." Strong vitriolic acid was called "oil" of vitriol, *from its oily appearance.*

300. *Aqueous sulphuric acid*, is made on the large scale, by mixing sulphur with one-eighth of its weight of nitre (NO_5+KO), and burning them in a furnace: the fumes, produced by the combustion, being transmitted, along with a current of atmospheric air, into a leaden chamber, the bottom of which is slightly inclined, and is covered with water. The oxygen of the atmosphere, forms sulphurous acid with some of the sulphur. Another portion of the latter, combines with three atoms of oxygen, belonging to the nitric acid of the nitre: and the sulphuric acid so formed, unites with the potash of the nitre, forming sulphate of potash. The residual nitric oxide is evolved, and is changed into hyponitrous acid [220], by the oxygen of the atmosphere. $(NO_5+KO)+S_2+O_3=(SO_3+KO)+SO_2+NO_2$. The sulphurous, and hyponitrous acids, pass into the leaden chamber; and the sulphate of potash, remains in the furnace. The mixed gases, in the presence of vapour of water—sometimes obtained from steam—and sulphuric acid, form nitro-sulphuric acid or sulphate of nitric oxide (SO_3+NO_2), a white crystalline compound, which is capable of being distilled unchanged. This sulphate, falling into the water, is decomposed into sulphuric acid, and nitric oxide. The former combines with the water: the latter ascends and, by absorbing oxygen from the atmosphere, again becomes hyponitrous acid. If it were not necessary to expel the residual nitrogen of the atmosphere from the chamber, which causes some of the hyponitrous acid to be lost, the same nitric oxide, would be sufficient to change any quantity of sulphurous into sulphuric acid.

Sulphurous and nitrous acids—particularly with the vapour of water—also form a crystalline solid (SO_3+NO_3). It is decomposed, by the larger quantity of water into which it falls; and the hyponitrous acid disengaged from it, forms nitric acid, which remains in solution, and nitric oxide which, with the oxygen of the air, becomes again hyponitrous acid. $3NO_3=NO_5+2NO_2$.

301. In the improved modes of manufacturing sulphuric *acid*, sulphur is burned in a furnace; and the resulting *sulphurous* acid is transmitted, along with fumes of nitric *acid*—evolved from nitrate of potash or soda, by means

sulphuric acid [229]—into the leaden chamber. Three atoms of oxygen, belonging to this nitric acid, combine directly with some of the sulphurous acid, changing three atoms of it into sulphuric acid; the nitric oxide, derived from the decomposed acid, becoming, as in the former process, hyponitrous acid, forms sulphate of nitric oxide: and the latter, by falling into the water, is resolved into sulphuric acid and nitric oxide, as before. When this process is employed, 1 lb. of sulphur will produce 3 lbs. of oil of vitriol (SO_3+HO): and only 3 lbs. nitrate of soda, are required for every 100 lbs. of sulphur.

302. The dilute sulphuric acid which, after some time, is formed in the leaden chamber, is deprived of a portion of its water, by boiling in leaden retorts. But, before it reaches the specific gravity of 1·750, it is removed into others, of glass, or platinum: since, at that temperature, it would act on the lead. When its specific gravity is 1·847, its boiling point being 617°, it would melt the lead, which fuses, at 612°.

303. The sulphuric acid of commerce is, generally found to have certain impurities. If, on diluting it with water, it becomes turbid, it contains sulphate of lead—which is only sparingly soluble in the dilute acid. It contains, also, occasionally, small quantities of nitric acid, formed in the leaden chamber; and, sometimes, sulphate of nitric oxide [300]—which corrodes the lead, and platinum. It is purified, by redistillation: the nitric acid passes off with the first products; and the sulphates of lead, and of nitric oxide, will be left behind in the retort. It is better, however, to decompose the latter sulphate, previous to distillation, by adding one-half per cent. sulphate of ammonia (SO_3+NH_4O):—the ammonia, and nitric oxide, will be changed into water, and nitrogen.

304. In distilling sulphuric acid, it will not be necessary to use a refrigerating apparatus [107]; since, as it exists in the vaporous form only at a high temperature, the atmosphere, alone, will condense it in the receiver. The sudden bursts of vapour, and the consequent fall of so heavy a liquid on the thin glass, renders it liable to break the retort in which it is distilled. This danger is, however, removed, *by placing* platinum wire or foil in the acid:—the

angles, cause the vapour to be gradually given off. Oerst and others, have remarked that fluids, having in them w or foil, boil at a lower temperature.

305. Oil of vitriol, the strongest aqueous sulphuric a we can obtain by concentration—and which may be kno by its giving off dense white fumes, during ebullition contains but one atom of water; its specific gravity 1·847; and it boils at 617°. When these fumes are p ceived, the process of concentration may be stopped.

306. Strong sulphuric acid acts on very few metals, cept at the boiling point. For, being an *ox*-acid [25] combines, not with the metal itself, but with its oxide; it has too strong an affinity for water, to allow that w which it is united, to be decomposed that the metal n take oxygen. The metal, therefore, must be already i state of oxide; or it must be oxidized, by decomposit of water—which is added to the acid, for the purp [180]. At the boiling point, the acid itself suffers deco position:—some of its oxygen combines with the metal form oxide; and sulphurous acid passes off. Below boiling point, the sulphuric displaces all other acids fr bases; but at a higher temperature, it is itself displac by certain weaker acids that are not volatile [130].

307. Sulphuric acid is very corrosive; it destroys, changes animal and vegetable substances, on account of affinity for water—which it forms, from a portion of th elements. Thus, in refining lamp oil, the mucillage charred by sulphuric acid, and then removed. W water is added to strong sulphuric acid, condensat occurs, and [35] great heat is evolved. Hence, the n ture must be made with caution; and, to prevent danger of explosion, the acid should be poured i the middle of a vortex, formed by stirring the w rapidly round with a glass rod:—the effect is still m violent, when the water is poured into the acid, t when the acid is poured into the water. When sulphu acid comes in contact with the animal body, it n be carefully wiped off with a dry substance, before w is applied: otherwise, the heat produced will be *injurious.* Sulphuric acid, having a specific gravity *1·780,* contains two atoms of water, and forms cry

at 32°. A stronger, or a weaker acid, requires a much lower temperature.

308. Dilute sulphuric acid, decomposes the compounds formed by salts of lead and animal substances. Hence, it is sometimes used as a preventative against "painter's colic." A few drops of it, added to a tolerably large quantity of cold water, makes an agreeable drink. All sulphates, are changed into sulphurets, by heating them with charcoal: this is frequently illustrated, in obtaining metals from their ores.

309. *Tests for Sulphuric Acid.*—The presence of sulphuric acid is detected, with great facility by a salt of barytes—the nitrate (NO_5+B*a*O) being generally used for the purpose. The affinity of sulphuric acid for barytes is so strong [133], that it will leave any substance, to combine with it and form sulphate of barytes, (SO_3+B*a*O). The latter, is a white precipitate: and is the only salt of barytes which is insoluble. It is not dissolved, even by nitric or hydrochloric acid at a boiling temperature. If the nitrate of barytes is—for example—added to a liquid containing sulphate of potash, sulphate of barytes will be thrown down, and nitrate of potash will remain in solution. (SO_3+KO)+(NO_5+B*a*O)=(SO_3+B*a*O)+(NO_5+KO.)

The other combinations of sulphur and oxygen, are not of sufficient importance to require notice.

310. It is supposed, that the compounds of sulphur and oxygen, are, in reality combinations of sulphurous acid—as a radical [19]—with oxygen. This opinion is rendered more probable, by the fact that sulphurous acid, only, can be formed by the direct union of oxygen and sulphur. It greatly simplifies the constitution of substances consisting of sulphur and oxygen, &c.:—for then

Hypo-sulphurous acid would be,	SO_2+S
Sulphuric acid,	SO_2+O
Chloro-sulphurous acid,	SO_2+*Cl*
Iodo-sulphurous acid,	SO_2+I
Nitro-sulphurous acid,	SO_2+NO
Hyposulphuric, or deutothionic acid,	$2SO_2$+O, &c.

311. Sulphuretted Hydrogen:—*symb.* HS; *equiv.* 17. It is called, also—and more correctly—"hydro-sulphuric acid," being an hydracid [21]. It is disengaged,

abundantly, from many animal, and vegetable substances, in a state of decomposition; and is formed in the intestines of living animals. It is evolved, in large quantities, from the water of what are called "sulphurous" mineral springs —such as that at Harrowgate, in England, and those of Golden-bridge and Lucan, in Ireland—the gas being, most likely, due to water acting on native sulphurets within the earth, at a high temperature.

312. Sulphuretted hydrogen, is obtained by the process used [180] to procure hydrogen—a sulphuret being used instead of the metal itself. Thus, with sulphuret of iron, sulphuretted hydrogen will be formed, and sulphate of iron will remain in solution. $(SO_3+HO)+FeS=HS+(SO_3+FeO)$.

313. Sulphuretted hydrogen, is a colourless gas; its smell is like that of rotten eggs—which owe their peculiar odour to its presence. Its specific gravity is 1·77:—100 cubic inches, weigh 54·891 grains. It is a combustible; and, when it is burned, sulphur is deposited. It does not support combustion, nor respiration. It is highly injurious to animals:—a horse has been killed, by an atmosphere containing but one part in 250 of this gas: air having only the one-eight-hundredth part of it, is poisonous to man; a cubic inch, introduced into the lungs, will cause instant death, although, in the intestinal canal, it is harmless. It will destroy life, by acting on only the surface of the body. Water absorbs, at ordinary temperatures, more than one volume, which is given out, by boiling; it is not absorbed by a concentrated solution of common salt. If collected over mercury, it is slowly decomposed. Strong nitric acid decomposes it, immediately:—which may be exemplified, by wrapping a bottle containing it in a cloth, dropping into it some nitric acid: then closing the mouth of the bottle, with the thumb, and shaking it—to bring the gas more rapidly in contact with the acid. An explosion and flame are produced, but are not dangerous:—they arise from combustion, caused by the heat evolved, when the gases are prevented from expanding. Sulphur—which is deposited in the bottle—water, and nitrous acid are the results. $SH+NO_5=S+HO+NO_4$. Sulphuretted hydrogen *is decomposed* also, by chlorine—on account of the

of the latter for hydrogen. The results then are, hloric acid (HCl), and sulphur. Hence, chlorine s an atmosphere, rendered unwholesome by this gas. id properties of sulphuretted hydrogen, are shown reddening litmus paper: which it does, even when ed in water.

Sulphuretted hydrogen precipitates, as we shall great number of the metals: sometimes, however, ires for this purpose, to be in combination with an If it is brought in contact with a solution contain- salt of an alkali or an earth, there is no precipitate: resulting sulphuret is soluble. Fig. 28 represents aratus, which has been found very convenient for itting sul- ted hydro- rough a n. The B contains and pieces phuret of Sulphuric poured in, h the fun- —accord- it is re- . The sul- ted hydro-

FIG. 28.

olved passes, by means of the angular tubes P and ving a caoutchouc joint [94]—into the bottle A, ning cold water, which purifies the gas, and retains ing else, that may pass from B. It is transmitted tube D—having a cork at E, into which is inserted ler tube—to the solution which is to be acted upon. . When sulphuretted hydrogen is present, in large ties, in the atmosphere, it darkens white paint— contains *ceruse* or carbonate of lead. Some fine s have thus been injured, when the varnish was re- by time. But Thenard found that they might be ly restored, by oxygenated water [199]: the *black* ret, being changed into *white* sulphate of lead. Sul- *ted hydrogen* causes silver to tarnish with great

rapidity; and it destroys the beautiful white colour of the subnitrate of bismuth, sometimes used by ladies as a cosmetic [279].

Bisulphuret of hydrogen, &c., are not sufficiently interesting to claim our particular attention.

316. SELENIUM:* *symb.* Se; *equiv.* 39·63. It is a very rare substance, and was discovered by Berzelius in 1818. It is found, united with metallic sulphurets, in the form of selenurets of the same metals.

317. It may be procured, from the sulphurets containing it, by adding eight times their weight of peroxide of manganese, and exposing the mixture to a low red heat, in a glass retort, the beak of which dips into water. The sulphur escapes, as sulphurous acid; and the selenium sublimes, either uncombined, or as selenious acid (SeO_2). Any of the latter which passes over into the water, will be reduced by the sulphurous acid.

318. Selenium is a dark brown solid, having, when smooth, a metallic lustre. Its specific gravity, is 43·20. It melts, at a little above 212°: and boils, at 650°—its vapour being of a deep yellow colour. It very much resembles sulphur, in its mode of combining, and, in the nature of its compounds: but, when burned in the air, it forms only an oxide (SeO). It gives to the oxidizing flame of a blow-pipe [101] a light blue tinge, and emits the smell of decayed horse-radish:—the one-fiftieth of a grain will scent a large room. This odour is due to oxide of selenium, formed. Selenuretted hydrogen (SH), is a gas which, if inhaled in extremely small quantity, destroys for a time the sense of smell, and causes considerable injury to the lungs.

Sulphuretted hydrogen precipitates, in acid solutions containing selenium, a yellow sulphuret (SeS_2), soluble in hydrosulphuret of ammonia.

319. PHOSPHORUS:†—*symb.* P: *equiv.* 31·32. It was discovered by Brandt, an alchymist, at Hamburg, in 1669; and was formerly obtained, by a very tedious, and disagreeable process, from urine; but it is now prepared from

* *Selēnē*, the moon, *Gr.*—a name suggested by its being, at first, mistaken for tellurium.

† *Phōs*, light; and *phero*, I carry. Gr.

bones, four-fifths of which are phosphate of lime (PO_5+CaO). Nature uses the salts of lime, for the framework of animals. When the carbonate predominates, it is "shell;" when the relative amount of phosphate is increased, it is "crust"—as in the shell of the lobster; when the phosphate of lime is in excess, it is "bone." We shall give, hereafter, the constituents of these substances.

320. After the bones are turned to a white powder, they are digested, for about two days, with half their weight of strong sulphuric acid: and enough of water to form them into a thin paste, is added. Sparingly soluble sulphate of lime (SO_3CaO), and soluble superphosphate of lime ($2PO_5$ +CaO), are produced. The latter is to be dissolved out with water, filtered, and evaporated to the consistence of syrup: it is then to be mixed with powdered charcoal, equal, in weight, to one-fourth of that of the bones used. The carbon, being heated along with it in an earthen retort, takes oxygen from some of the phosphoric acid of the superphosphate, forming phosphate of lime (PO_5+CaO), carbonic oxide [263], and carbonic acid [266]; and the phosphorus is driven off in vapour, and is condensed by the water into which the beak of the retort is plunged.

321. Phosphorus is, usually, a semi-transparent, and nearly colourless substance, which may be cut with a knife; but at 32° it is crystalline, and brittle. Its specific gravity, is 1·77. It melts, at 108°: takes fire, in pure oxygen, at 80°—but, in common air, at 148°: and boils, at 550°. It burns slowly in the atmosphere, at ordinary temperatures, with the emission of light; but this slow combustion will be prevented, by olefiant gas, the vapour of ether, or of oil of turpentine. It takes fire spontaneously, if placed on blotting paper, and sprinkled with soot: the latter condenses the gases of the atmosphere, and brings them in closer contact with the phosphorus. It may be inflamed under water, by a current of chlorine, or, if the water is heated [124], by a current of oxygen. When chlorine is used, terchloride of phosphorus (PCl_3) is formed; and this is decomposed, by the water, into hydrochloric (HCl), and phosphorous (PO_3) acids. $PCl_3+3HO=3HCl+PO_3$.

If phosphorus is dissolved in ether, the solution will, on

exposure to the air, become luminous, as will also the face, and hands, if rubbed with it: this may be done, without any other inconvenience, than what arises from the disagreeable odour. If some of the solution of phosphorus is thrown on a lump of sugar, and the latter is then thrown into hot water, the ether and phosphorus will ascend through the water, in vapour, and inflame at the surface. If thrown on blotting paper, it will take fire, when the ether has evaporated. If phosphorus and azote are kept in contact, they will unite: and the gas will become luminous, when brought in contact with atmospheric air.

Phosphorus is found to assume *allotropic* [154] conditions. For, when it is strongly heated, and suddenly cooled, it becomes quite black; but it gradually assumes its ordinary appearance. It has been produced, also, in a peculiar form, in which it is called "allotropic" or "red phosphorus." In this state it is amorphous, opaque, and reddish; it is non-luminous in the dark; and is not ignited by friction, or percussion, at a temperature less than about 482°, Fahrenheit. But, combined with chlorate of potash, &c., it is highly inflammable. If used in the manufacture of lucifer matches, it is not at all injurious to the workmen: while common phosphorus is productive of a most frightful malady, which at first seems an ordinary toothache, but ends in a loathsome and extremely painful disease, terminating in the loss of the greater part of the lower jaw-bone. The matches, made with this kind of phosphorus, are not poisonous; they have little or no smell: and are not hygrometric, nor liable to be inflamed by accident. The amorphous state, is produced by exposing phosphorus, in a suitable apparatus, to a temperature which is gradually raised as high as 500°, Fahrenheit—at which it is kept for some time. If too high a temperature were employed, a violent explosion would occur: and the amorphous would be suddenly changed into ordinary phosphorus.

322. Phosphorus forms with oxygen, oxide (P_2O; 70·64); hypophosphorous acid (PO; 39·32); phosphorous acid (PO_3; 55·32); and phosphoric acid (PO_5; 71·32), which is always produced when phosphorus is burned with a sufficient quantity of oxygen, and at a high temperature. It forms several compounds with hydrogen, of which the

remarkable is phosphuretted hydrogen (PH_3; 34·32). rms, with chlorine, protochloride (PCl_3; 137·73), and hloride (PCl_5; 208·67): and combines, also, with r elements.

23. Compounds of Phosphorus. Phosphorous ɔ:—*symb.* PO_3; *equiv.* 55·32. This acid may be ob- ed, by throwing a current of chlorine upon phosphorus, ed in a thin glass vessel, and covered to the depth of inches with water. The protochloride of phosphorus l_3), which results, is immediately decomposed by the r, phosphorous and hydrochloric acids being produced. $_3+3HO=PO_3+3HCl$. Evaporating the solution, to consistence of syrup, drives off the hydrochloric acid, leaves hydrated phosphorous acid behind.

24. Phosphoric Acid:—*symb.* PO_5; *equiv.* 71·32. acid as we have already remarked [27], is, according ircumstances, capable of combining with one, two, or , atoms of base. There is, therefore, a monobasic (PO_5+HO), termed the *metaphosphoric:* a bibasic $+2HO$), the *pyrophosphoric:* and a tribasic (PO_5+)), the ordinary phosphoric acid. It is found combined magnesia and ammonia, in the outer husks of all the ses. Hence it is present in flour, and in beer: and it times forms very large concretions in the cœcum of ers' horses. It is detected, in beer, by its forming a e precipitate, when ammonia is added. It is one of onstituents of bones, &c. [319].

25. Phosphuretted Hydrogen:—*symb.* PH_3; *equiv.* 2. It is obtained, by *filling* a retort, containing a l quantity of phosphorus, with a solution of caustic sh. If any atmospheric air is allowed to remain in upper part, an explosion may occur. This will, how- , be prevented by letting up a little ether, the vapour hich, or of any of the essential oils, changes the gas luced into one that is not spontaneously inflammable. en the retort is placed in a solution of common salt, to re a proper temperature, and prevent danger from the sphorus if the retort should break, and heat is applied, r is decomposed, hypophosphorous acid (PO)—which bines with potash—and phosphuretted hydrogen (PH_3), g *formed.* $4P+3KO+3HO=3(PO+KO)+PH_3$.

The phosphuretted hydrogen, as it rises from the water into which the beak of the retort is plunged, bursts into a flame: which is succeeded by a ring of smoke, consisting of a vast number of small rings revolving rapidly on axes, the planes of which are perpendicular to that of the general ring produced by them. The latter widens as it ascends, and will continue unbroken for a longer, or shorter period, according to the stillness of the air in the apartment. When the gas is transmitted into a jar of oxygen, the effect is very beautiful, but the experiment is not so safe. The retort must not be removed, until all the gas has been expelled by the vapour of water.

326. Phosphuretted hydrogen is transparent, and colourless; it has a very disagreeable taste, and the smell of garlic. Its specific gravity is 1·185:—100 cubic inches weigh 36·7489 grains. It does not support either combustion or respiration. Some persons believe that the spontaneous combustion of the human body—of which several cases, seemingly well authenticated, are on record—arises from the production of this gas, by disease.

327. Phosphuretted hydrogen, not spontaneously inflammable, but exactly the same, in composition, &c., as that which is, may be obtained, by heating hydrated phosphorous acid (PO_3+3HO) [323]. Water is decomposed, phosphoric acid (PO_5), and phosphuretted hydrogen (PH_3), being produced. $4(PO_3+3HO)=3PO_5+PH_3$. This gas may be set on fire. It is changed into the spontaneously inflammable kind, by nitric oxide, or nitrous acid gas. The spontaneous inflammability of phosphuretted hydrogen, arises from the presence of a highly volatile fluid (PH_2).

328. Chlorine:*—*symb.* Cl; *equiv.* 35·47. It was discovered by Scheele, in 1774; and was named by him "dephlogisticated marine acid," because supposed to be hydrochloric acid deprived of its phlogiston [161]. It was afterwards called "oxy-muriatic acid"—being considered a combination of muriatic acid and oxygen, &c. It is found, in enormous quantities, in combination as chloride of sodium ($NaCl$) or common salt: and is obtained, by adding peroxide of manganese to hydrochloric acid, and applying heat—after stirring the mixture, to allow any

* *Chlōros*, green, Gr., from its colour.

nic acid that may be present, to escape. Chloride of anese—which remains in the retort—water, and chlo- are the results. $MnO_2+2HCl=MnCl+2HO+Cl$. -chloride of manganese ($MnCl_2$), is first produced: is decomposed by a moderate heat. Since chlorine orbed by water at a low temperature, and it acts upon ury, it must be collected over water heated to beyond or saturated with common salt. Or, it may be col- without the use of any fluid: since, being heavier atmospheric air, it will [226] displace the latter from into which it is transmitted.

). Chlorine is of a greenish colour, and of a very dis- able taste and smell. It is a supporter of combus- but is not inflammable. Copper leaf, pulverized ony, arsenic, or zinc, tinfoil, and phosphorus, burn in ntaneously. A wax taper introduced into it, will ue lighted; but its brilliancy will be greatly dimin- : and as its hydrogen, only, combines with the ne, a dense black smoke, consisting of the carbon, e produced. Paper, dipped in oil of turpentine, will ire in chlorine: and, for a similar reason, large quan- of soot will be formed. Chlorine is irrespirable, an irritant, and very suffocating gas. Its specific y, is 2·47:—100 cubic inches, weigh 76·5989 grains. water absorbs two volumes of it, and then possesses of the properties of the gas itself: but light causes hlorine gradually to decompose the water, and form chloric acid (HCl), by combining with its hydrogen. chlorine water is cooled to 36°, hydrate of chlorine ates, in the form of yellow crystalline plates. These in 27·7 chlorine, and 72·3 water: they liquefy at nd the gas flies off. When chlorine is passed into , some of the latter is decomposed, hydrochloric acid formed, and oxygen—which forms chlorous acid, and nated water—being set free. Hence, if the solution osed to sunlight, oxygen is continually evolved: and hole of the chlorine, ultimately, forms hydrochloric For this reason, chlorine water acts powerfully on able fibres, the chlorine taking their hydrogen, and volved oxygen, their colouring matter: and, conse- ly, alkaline bases are required to modify the effect.

The tendency of this gas to unite with hydroge
ing to some chemists, gives to it the property of
for, when it combines with that of decomposed
oxygen, which is liberated, burns the colourin
And, according to this theory, oxygen is the rea
bleaching; the result being the same, whether
slowly, by exposure to atmospheric air, or more
the use of chlorine, which affords oxygen in th
state [126]. The effect cannot be due to the
itself, if the colour is not affected when the chlo
—that is, when there is no water present, whi
decomposed: which has been stated. More
searches, however, seem to show that the chlorin
cases, actually combines with the colouring ma
in others, it takes the place of hydrogen, in t
that, in others, besides combining with, it m
oxidizes them—water being decomposed.

330. The affinity of chlorine for hydrogen, c
be a powerful disinfectant:—it purifies the air
ious effluvia, by seizing upon the hydrogen the
The same property causes it, also, to act fre
a very efficient oxidizing agent—by liberatin
when it decomposes water, that it may combin
hydrogen. Sometimes, it more fully oxidizes
oxide, by combining with a part of its metal
placed oxygen going to the other portions of
which thus becomes in a higher state of oxid
this way, it changes protoxide into peroxide o
chlorine is transmitted through sulphuric ether,
is decomposed, and the bubbles of gas inflame, a
temperatures, as they ascend:—hydrochloric aci
lon are the results. At a pressure of about fo
pheres, chlorine becomes a bright yellow liquid
a non-conductor of electricity. In the form of g
be kept in a bottle for a long time, if the gro
stopper is well greased.

331. Chlorine forms, with oxygen, hypochl
(ClO; 43·47); chlorous acid (ClO_3; 59·47); p
acid (ClO_4; 67·47); chloroso-chloric acid (Cl_2O_5
$2ClO_3$; 91·941)—called by Sir H. Davy, *euchlori
acid* (ClO_3; 75·47); perchloric acid (ClO_7; 9

chloroso-perchloric acid ($Cl_2O_{17}=ClO_3+2ClO_7$; 242·41). It forms, with hydrogen, hydrochloric acid (HCl; 36·47). With carbon, subchloride or dichloride (C_2Cl; 47·47); protochloride (CCl; 41·47); and perchloride (C_2Cl_3; 118·41). With sulphur, dichloride (S_2Cl; 67·47); and bichloride (SCl_2; 86·94). With phosphorus, protochloride (PCl_3; 137·73); and perchloride (PCl_5; 208·67). With boron, bichloride (BCl_2; 81·84). With silicon, chloride ($SiCl_2$; 92·29). It forms, with carbon, chlorocarbonic acid $COCl$; 49·47), &c.

332. Sometimes, chlorine unites with metallic oxides:—thus, with lime, it forms chloride of lime ($CaOCl$.) At others, a chloride combines with an oxide of the same, or of a different metal, forming an oxy-chloride or submuriate:—thus, oxy-chloride of copper is produced [gal. 22], when sea water acts on copper.

333. *Tests for Chlorine.*—Chlorine, in the free state, is detected by its odour. Also, by giving, with nitrate of silver (NO_5+AgO), a white curdy precipitate, the chloride of silver ($AgCl$). Nitric acid is liberated, and chloric acid (ClO) is formed, with the oxygen of the oxide and a portion of the chlorine. $6Cl+5(NO_5+AgO)=5AgCl+5NO_5+ClO_5$. The chloride is [opt. 120] blackened, by exposure to light. Organic matter must be present, to afford hydrogen, which, combining with the chlorine, forms hydrochloric acid, metallic silver, in a finely divided state, being set free.

334. If the chlorine is in combination, the oxygen and nitric acid go to the substance with which it was combined. Thus, when nitrate of silver is added to a solution of common salt ($NaCl$), chloride of silver, and nitrate of soda (NO_5+NaO) are the results. $NaCl+(NO_5+AgO)=AgCl+(NO_5+NaO.)$

335. Chlorine, as chloric acid, gives no precipitate with nitrate of silver. The alkaline chlorates, however, when ignited, become chlorides, oxygen being disengaged: and most of the other chlorates are changed, by heat, into oxides—a mixture of chlorine and oxygen being evolved.

336. Chloride of silver may be distinguished from the iodide, which is yellow, by its whiteness: and by its being soluble *in water of ammonia*—the precipitate thrown down

from the latter by nitric acid, not being dissolved by it even at a boiling temperature. It may be distinguished from the cyanide—which, if ignited, yields metallic silver—by not being decomposed with heat; from the pyro phosphate, by becoming yellow, on being boiled with phosphate of soda; and from the bromide, by the latter giving off vapours of bromine, when heated with chlorine water.

337. Chloride of silver is dissolved, to a small amount by a solution of common salt, or hydrochloric acid. It is this minute quantity which acts, when nitrate of silver is given as a medicine:—the nitrate is changed into chloride by the hydrochloric acid of the gastric juice. If the chloride were quite insoluble, it would cause no effects:—many antidotes produce their beneficial results, by rendering poisonous substances insoluble.

338. The air hanging over the sea, will make a solution of nitrate of silver turbid, on account of the common salt ($NaCl$) it contains—the evaporating water having communicated to the solid, the property of evaporation, which it does not possess in the dry state [heat 88]. Hence, it is difficult to purify sea water perfectly, by distillation since, a portion of the substances it holds in solution, rises along with it. The process has, however, of late been greatly improved: and it is often obtained in ships, by means of an apparatus so contrived, that the fires used in cooking supply it in large quantities. It descends into the tanks, and is aerated, by the motion of the ship, which causes it to combine with atmospheric air. If required for immediate use, this combination is effected, so as to give it the briskness of spring water, by transmitting through it a current of electricity from a self-acting apparatus.

339. Compounds of Chlorine. Hypochlorous Acid. Bleaching Salts, &c. Hypochlorous acid:—*symb.* ClO, *equiv.* 43·47; is remarkable only for its bleaching properties; and from its being, according to many chemists, the constituent of what are called "bleaching salts." The old method of bleaching, by exposure to the air, was extremely tedious; that, in which chlorine, and some of its compounds are employed, for the same purpose—and which was introduced only a few years ago—is rapid, and most complete. *Chlorine* may be used for bleaching, in several ways.

may be dissolved in the water, in which the cloth is steeped:—this is both economical and effective; but it is injurious to the health of the workmen: and, also, without great caution, to the texture of the cloth. Or it may be passed into cream of lime [282]: and, water being added, the cloth may be steeped in the mixture. Or, finally, chlorine may be transmitted into hydrate of lime: when a white powder, which has merely a faint odour of hypochlorous acid, and is the substance at present employed in bleaching, will be produced. Anhydrous lime, would not absorb the gas.

340. According to some, the bleaching salt of lime consists of chlorine, combined with lime ($CaOCl$). According to others, it is a compound of chloride and hypochlorite of lime [$CaCl+(ClO+CaO)$]. In either case, it is supposed to consist of the same elements—since $2CaOCl=CaCl+ClO+CaO$. If chloride of calcium is present, it must be in combination; since, in a free state, it would cause the salt to deliquesce—which it never does, unless improperly prepared. If too large a quantity of chlorine is used in its manufacture, or if it is kept too long, it will become chlorate of lime, and chloride of calcium—after which, it will attract moisture, and will no longer bleach. When the bleaching powder is thrown into water, only a part of it is dissolved, and some hydrate of lime falls down: the latter not being converted into the bleaching compound, from, it is probable, the mechanical disadvantage attending the use of the dry lime. If the lime were mixed with water, before it was combined with the chlorine, the whole of it would be dissolved.

341. Any acid will decompose the bleaching powder, and liberate the chlorine. Goods dyed red with madder, and stamped with tartaric acid thickened with gum, are bleached in the pattern—being acted on only where there is acid. Even the carbonic acid in water, or that of the atmosphere, will slowly disengage the chlorine.

342. The goodness of a bleaching salt may be ascertained, by finding how much of it will change a known quantity of protochloride of mercury (calomel, Hg_2Cl), suspended in water, into perchloride (corrosive sublimate, $HgCl$), *which will be* completely dissolved by that fluid.

23561 grains protochloride of mercury, require 3547 parts chlorine, to change it into perchloride. Theoretically, the bleaching salt should contain 42·5 per cent. chlorine; but the best specimens, have scarcely more than 40·32; and the generality of them, only about 30 per cent. The determination of the quantity of chlorine in a bleaching salt, is termed "chlorimetry."

343. A bleaching salt of potash, or soda, may be formed, by transmitting chlorine into solutions of their carbonates, until no more chlorine is absorbed:—the yellow colour of the fluid, is due to the presence of free hypochlorous acid. Rather complicated changes occur during the process; but the result is, that the carbonates become hypochlorites.

High pressure steam is, sometimes, used instead of chlorine for bleaching.

344. The solution of a bleaching salt, is employed as a disinfecting fluid. That of lime will answer the purpose, without the addition of water, if a large surface is exposed to the carbonic acid of the atmosphere. Chlorine itself, though highly effective, is in many cases, inadmissible.

345. The solution of a bleaching salt will, also, restore meat which is beginning to putrefy. That of soda is the most convenient, in this case: since the results are water, and common salt ($NaCl$): and the latter is useful, rather than the contrary.

346. Chlorous Acid:—*symb.* ClO_3; *equiv.* 59·47. It is obtained, by acting on chloric acid, with an equal number of atoms of arsenious acid. Chlorous, and arsenic acids, are the results. $ClO_5 + AsO_3 = ClO_3 + AsO_5$. A gentle heat separates the chlorous acid from the liquid, in the form of a greenish yellow gas. If the temperature employed is not very moderate, a violent explosion may happen—the gas being decomposed into chlorine, and oxygen. It bleaches powerfully.

347. Perchlorous Acid:—*symb.* ClO_4; *equiv.* 67·47. It is obtained, by decomposing chlorate of potash, in fine powder, with tolerably strong sulphuric acid. The chloric acid, is resolved into perchlorous (ClO_4), and perchloric (ClO_7) acids. $3ClO_5 = 2ClO_4 + ClO_7$. Bisulphate, and perchlorate of potash, remain behind. The heat must be *very gentle*, or an explosion will take place. This gas,

being heavier than atmospheric air, will displace the latter from a jar [226].

348. Perchlorous acid is of a yellowish green colour, and an aromatic odour. It is condensed, by pressure, into a deep red fluid. It bleaches powerfully; and, on account of the facility with which, from almost no cause, it separates into its elements, it oxidizes energetically. If a few crystals of chlorate of potash, and a little phosphorus, are placed together, at the bottom of a tall glass, filled with water, and some strong sulphuric acid is conducted to them, by means of a long glass funnel, bubbles of perchlorous acid, in each of which the phosphorus burns, are produced: and thus combustion is effected, under water.

If perchlorous acid is heated, to even a little above 212°, it explodes, with a flash of light.

349. Chloric Acid:—*symb.* ClO_5; *equiv.* 75·47. It is obtained, by adding to a solution of chlorate of barytes (ClO_5+BaO), just enough of sulphuric acid for saturation:—sulphate of barytes (SO_3+BaO) will be thrown down, and chloric acid will remain in the fluid.

350. Hydrochloric Acid:—*symb.* HCl; *equiv.* 36·47. It was formerly called "spirit of salt," "marine acid," and "acid of salt," and, very commonly, muriatic acid:* but it is now generally termed, with greater accuracy, "hydrochloric acid"—which indicates its composition. It was first obtained, as a gas, by Priestly, in 1772. Light [opt. 120], will cause hydrogen and chlorine to combine and form this acid. It may be procured, very conveniently, from one part, by weight, of dried common salt ($NaCl$), which has been ignited to decompose any nitre present, and two parts oil of vitriol. When heat is applied, the hydrochloric acid will be evolved, in the form of gas: and according to the quantity of sulphuric acid, sulphate, or bisulphate of soda, will remain in the retort. The reasons given for forming a bisulphate, in obtaining nitric acid [230], are applicable, in this case also: since the sulphate, or bisulphate, of soda is affected in the same way as the sulphate, or bisulphate, of potash: and there are, in both instances, the same motives, for adding enough sulphuric acid to form a bisulphate. But, in obtaining the hydrochloric acid, it

* *Muria*, sea salt. *Lat.*

charcoal, is to be changed into carbonate of soda—is made on the large scale, from common salt, the hydrochloric acid, passing into the atmosphere, falls on, and utterly destroys, the surrounding vegetation. To diminish the evil, chimneys of immense height are constructed; and the gases, being carried by them to a great altitude, are so much diluted, before they reach the earth, that the injury they produce is greatly lessened. The chimney of Muspratt, between Manchester and Liverpool, rises to the height of 492 feet—it is 30½ feet in diameter at the base, and 11 at the top: and required, for its construction, a million of bricks.

356. In some cases, the acid is partially condensed, by transmission through flints wetted with water. But the best plan is, to combine the manufacture of bleaching powder [339] with that of the sulphate of soda. In this case, the chlorine—which is set free, by decomposing the hydrochloric acid, as fast as produced, with peroxide of manganese [328]—is condensed with lime [339]: and, the salts of iron and manganese being decomposed by exposure to the atmospheric air, at a red heat, the sulphate of soda is dissolved out from out the residue.

357. Hydrochloric acid, is one of the ingredients of the "gastric juice," which is so important an agent in the process of digestion. It is derived from the salt consumed with the food; and is the more necessary, in proportion as the food is difficult to be digested.

358. Aqua Regia.* It is termed, also "nitro-muriatic acid," and by some, on account of being considered a new compound (NCl_2O_3), "chloro-nitrous acid:"—but the latter, has been ascertained to be merely a mixture of chlorine and hyponitrous acid. It is formed, by adding nitric to an equal quantity of hydrochloric acid: water, chlorine, and nitrous acid, being the results. $NO_5+HCl=HO+Cl+NO_4$. When the two acids are mixed, a yellow fluid, having the smell of chlorine and nitrous acid, is produced; and heat is evolved. But the mutual decomposition of the acids, proceeds no farther than to saturate the liquid with chlorine; and if this is driven off by heat, or is combined with a metal, a new quantity is disengaged. The nitro-

* Royal water, *Lat.*—So called, because it dissolves gold, which *was termed* the "king of metals."

muriatic acid is, therefore, a source of chlorine in the nascent state, which [126] is very favourable to chemical combination; and it dissolves gold, platinum, &c.—that are not acted upon by either of the acids separately.

359. Iodine:*—*symb.* I; *equiv.* 126·85. It was discovered by Courtois, at Paris, in 1812: and is found in nature, generally in combination with potassium or sodium, but never in a free state. It occurs in many springs, in the oyster, sponge, &c. The one-millionth part, by weight, of marine plants is iodine. It was long known, that the ashes of the sponge were useful, in the cure of scrofula, &c. This gave rise to a suspicion, afterwards proved to be correct, that their utility was due to the iodine they contained; and that substance has been successfully substituted for the ashes, previously employed. The inhalation of the vapour of iodine—by breathing air which has passed through water containing it in solution—and other applications of it, have been found beneficial in bronchitic affections, &c.

360. Iodine may be obtained from *kelp*—the semi-fused ashes, which remain after sea-weed has been burned. For this purpose, the kelp is lixiviated with water, which dissolves the soluble salts: and, the solution being then concentrated to a certain point, common salt, with carbonate and sulphate of soda, fall down, and may be removed: and, on cooling the liquor, chloride of potassium separates in the crystalline form, and may also be taken away. This concentration, and subsequent cooling, is repeated until these salts are exhausted, and only a dense and dark liquid, containing the iodine—in combination, probably, with sodium—and various salts, remains. This liquid is to be rendered extremely sour, by the addition of sulphuric acid, which, with the iodine of sodium, forms the double sulphate of soda and water, and hydriodic acid. $NaI+2(SO+HO)=[(SO_3+NaO)+(SO_3+HO)]+HI$. During the process, carbonic acid, sulphurous acid, and sulphuretted hydrogen, are given off—on account of other salts, also, being decomposed by the sulphuric acid. After a day or two, the liquor in which the hydriodic acid has been formed, is to be heated with peroxide of manganese. The latter, with the hydriodic acid, forms iodide of manganese and water, iodine

* *Iōdēs*, violet coloured. Gr.

being set free. $2HI+MnO_2=MnI+2HO+I$ [328]. The iodine, driven off by the heat, is condensed in the form of dark and brilliant crystalline plates, on the cold surface of a globular vessel filled with water, placed to intercept it. As the sulphuric acid would form also hydrochloric acid, from the chlorides present, to prevent the simultaneous evolution of chlorine—which would immediately combine with the iodine, and form a chloride of iodine—only enough sulphuric acid to decompose the iodides, must be used.

361. Iodine, in the form of *vapour*, is of a beautiful violet colour—whence its name; but this colour disappears, if the vapour is condensed. In the form of crystalline scales, its specific gravity is 4·948. It fuses at 225°, and boils at 347°:—but, when there is moisture present, it sublimes rapidly, at a heat below that of boiling water; it even evaporates freely, at the ordinary temperature of the atmosphere. It stains the skin, but the discolouration is not permanent. It is not a conductor of electricity, and, therefore, although its lustre is strikingly metallic, it is not considered a metal. But, like some other bodies, it is said to be a conductor when its particles are brought into closer contact—which may be effected by fusion. Substances, undoubtedly metallic, have been found to lose their power of conduction, when in a certain state of division [elect. 20]. It is not inflammable: but is a powerful supporter of combustion, and will immediately inflame phosphorus brought in contact with it. It is an irritant poison. Water dissolves only the one-seven-thousandth of its weight of iodine: but it is very soluble in alcohol, or ether. When taken into the stomach, as an alcoholic solution, it is precipitated, on account of the dilution of the alcohol by the other fluids found there. Iodine bleaches, like chlorine, and for the same reasons [329]: but not so powerfully.

362. Iodine forms, with oxygen, iodoso-iodic acid (I_2O_{15}; 786·25); iodous acid (IO_4; 158·85); iodic acid (IO_5; 166·85); and periodic acid (IO_7; 182·85). With hydrogen, hydriodic acid (HI; 127·85); with nitrogen, teriodide (NI_3; 394·57), which is explosive, like the analogous compound of chlorine [257], though not altogether to the same extent. Iodine combines, also, with chlorine, &c.

363. Tests for Iodine.—Iodine, in the free state, is

readily detected by a *cold* solution of starch: with which it forms a deep blue compound—iodide of starch. Hot water dissolves the blue precipitate, and forms with it a colourless solution, which, however, regains its colour when cooled. If the iodine is in combination, it must be set free by an acid: or, by pouring on the solution containing it, the supernatent chlorine, from a bottle of chlorine water. The latter, to those who are not aware of the reason, appears to produce an exceedingly curious effect:—for, as the bottle of chlorine water seems merely to be held over the fluid containing the iodine and starch, the sudden change of colour seems quite unaccountable. If, in looking for iodine, too much chlorine is added, a chloride of iodine will be formed; and the blue colour will disappear. Alkalies, or any other substances, forming compounds with iodine, would produce the same effect. Starch is an extremely delicate test.

364. BROMINE:*—*symb.* Br. *equiv.* 79·97. It was discovered in 1836, by Balard, of Montpelier: and is associated with chlorine, and iodine, in sea water, &c. It may be obtained, by transmitting a current of chlorine through *bittern*—the "mother liquor" whence common salt has been procured: the fluid then acquires a yellowish hue, on account of the bromine, which is set free by the chlorine —the latter having, through a stronger affinity, taken its place in combination. The liquor is next to be agitated with ether, which will dissolve the bromine: and the resulting ethereal solution, which floats on the top, is to be removed, and potash is to be added to it. Bromide of potassium (KBr), and bromate of potash (BrO_5+KO) will be formed. $6Br+6KO=5KBr+(BrO_5+KO)$. On separating the ether, by evaporation, and fusing the mixed salt which remains, the bromate will be changed into bromide of potassium, in the same way as chlorate is changed into chloride of potassium [157]. Sulphuric acid and peroxide of manganese being then added to the bromide, and heat being applied, bromine will be evolved. The changes, which take place, are analogous to those occurring, when chlorine is obtained from a chloride, or iodine from an iodide. The bromide of potassium and sulphuric acid, form

* *Bromos*, a disagreeable smell. Gr.

the double sulphate of potash and water, and hydrol
acid. $KBr+2(SO_3+HO)=[(SO_3+KO)+(SO_3+$
$+HBr$. The hydrobromic acid and peroxide of mang
form bromide of manganese and water, bromine be
free. $2HBr+MnO_2=MnBr+2HO+Br$.

365. Bromine, at ordinary temperatures, is a de
fluid by transmitted, but a black by reflected ligh
odour is very disagreeable, and its vapour highly d
ous, when inhaled even in very small quantities. A
by incautiously opening the bottle in which it is cont
the smallest particle gets into the eye, that organ is f
destroyed. It is a non-conductor of electricity. I
cific gravity is 2·97. At ordinary temperatures, it gi
fumes resembling, in appearance, those of nitrous
and, unless kept in water, its vapour is sometimes
gaged in such quantities as to burst the bottle. It so
at a temperature of 4°, and boils at 116°. Like ch
it sets fire to some of the metals. It bleaches, but
a yellow stain. It is sparingly soluble in water: b
solves abundantly in alcohol, and ether.

366. Bromine forms, with oxygen, bromic acid (
119·97). With hydrogen, hydrobromic acid (HBr; 8
With sulphur, bisulphuret (BrS_2; 111·97). With
phorus, two phosphurets (PBr_3; 271·23, and
431·17). It unites, also, with chlorine, and iodine,

367. *Tests for Bromine.*—Bromine is recognis
giving, with nitrate of silver, a curdy white preci
which dissolves with difficulty in water of ammonia
which, heated with chlorine water, evolves vapour o
mine. It gives, with acetate of lead, a white prec
that, unlike chloride of lead, does not dissolve in wat
gives, with starch, a yellow precipitate.

368. FLUORINE:—*symb.* F; *equiv.* 18·86. It ha
strong affinities, that it is not certainly known to hav
been insulated. It is obtained, most probably, wh
looking for it, vessels are used, which consist of a sub
—fluor spar, for example—already saturated with
dry chlorine is, with this precaution, transmitted int
ride of mercury (HgF), heat being applied, a colo
gas, which acts violently on metallic foils, results. H
$Cl=HgCl+F$. This, however, may be chloride of flu

369. Fluorine does not unite with oxygen. It forms, with hydrogen, hydrofluoric acid (HF; 19·86). With phosphorus, terfluoride (PF_3; 87·90). It combines with sulphur, &c.

370. Compounds of Fluorine. Hydrofluoric Acid:—*symb.* HF; *equiv.* 19·86. This is the most important of all the compounds of fluorine. It is obtained, by acting on Derbyshire spar (C*a*F), reduced to powder, with twice its weight of strong sulphuric acid: and heating the mixture, in a large leaden retort. Hydrofluoric acid distils over, and must be collected in a receiver cooled with ice:—sulphate of lime is left behind. $CaF+(SO_3+HO)=HF+(SO_3+CaO)$.

371. Hydrofluoric acid is a colourless liquid. Its specific gravity is 1·0609: but water, for which it has a strong affinity,—though a lighter fluid—increases its density, the mixture being accompanied by condensation, the evolution of heat, and a hissing noise, like that produced by plunging red-hot iron into water. It boils at 60°, but, at a temperature of 59°, unless the vessel in which it is kept is well stopped, it escapes in dense white fumes. It is most corrosive, and acts so powerfully on animal matter, that even its vapours produce malignant ulcers. Hence, on account of its dangerous nature, it is usually prepared in a dilute state—water being, for this purpose, put into the receiver into which it is distilled. It does not act on gold, silver, platinum, or lead; but it acts powerfully on the solder with which vessels are joined. It dissolves silicic, titanic, molybdic, and tungstic acids.

372. The effect produced by this acid on glass, and which arises from its affinity for silicon, enables us to engrave that substance, by means of it, with great facility. Bottles for the laboratory may be labelled, by coating them, where they are to be protected from the acid, with beeswax: then drawing the letters, &c., in the latter, so as to uncover the surface of the glass where it is to be acted upon; and afterwards, holding the bottle over the gas, as it is disengaged from fluor spar by means of sulphuric acid [370]—great care being taken [371], to prevent the vapours from coming in contact with the skin, or very painful wounds will be produced. The silex (SiO_3)—contained

in the glass—and the hydrofluoric acid, form terfluoride of silicon (SiF_3), and water. $SiO_3+3HF=SiF_3+3HO$. Without proper precaution, other glass vessels which are near, will be dimmed on their surfaces. Hydrofluoric acid was first used to engrave glass, at Nuremburg, in 1670; but the nature of the process was kept secret.

373. Silicon:—*symb.* Si; *equiv.* 21·35. Sir H. Davy first obtained it, by bringing the earth silex in contact with the vapour of potassium, silicate of potash, and silicon, being the result. But it is now procured, by means of the double fluoride of silicon and potassium (SiF_3+KF), dried at a temperature approaching to redness, and heated in a hard glass tube in contact with potassium (K): fluoride of potassium is formed, and silicon is set free. $(SiF_3+KF)+3K=4KF+Si$. The fluoride of potassium being dissolved out, silicon is left behind.

374. Silicon is a dull brown powder, having no metallic lustre, and being incapable of conducting electricity:—it is not, however, yet ascertained, with certainty, whether or not it is a metal. It burns brilliantly in oxygen, on account of the small quantity of hydrogen, generally, in combination with it; and it is soluble in a mixture of nitric and hydrofluoric acid: but it is rendered quite incombustible, and insoluble, by heating in a closely covered vessel.

375. Silicon forms with oxygen, silicic acid (SiO_3; 45·35)—or silex. With chlorine, chloride of silicon ($SiCl_3$; 127·76). With fluorine, fluoride of silicon (SiF_3; 77·93). This gives rise to a double fluoride of hydrogen and silicon (SiF_3+HF) or hydrofluosilicic acid, the hydrogen of which, in the formation of *fluosilicates* or *double fluorides*, is replaced by a metal;—which is exemplified by the fluosilicate of potassium (SiF_3+KF).

376. Compounds of Silicon. Silex:*—*symb.* SiO_3; *equiv.* 45·35. This is called, also, silicic acid: and is found in the outer parts of the leaves, and the stalks of all the grasses—in the form of silicate of potash. It is present in most minerals; and constitutes the base of the quartz family. Silex may be obtained, by melting in a platinum crucible, a mixture containing equal weights of

* *Silex*, a flint. Lat.

carbonate of potash (CO_2+KO) and carbonate of soda (CO_2+NaO): and, when the mixture is in a state of fusion, dropping powdered flint into it, in small quantities at a time. The flint will be dissolved, and its silex will combine with the potash and soda, forming silicates of these alkalies, the carbonic acid being driven off. The carbonate of soda, renders the compound more fusible and soluble. When flint is no longer dissolved, water having been added, the solution is filtered, and an acid is poured into the clear liquor. This causes the silex to precipitate, as a white gelatinous hydrate: which being dried and heated, becomes a gritty insoluble powder.

377. The specific gravity of this powder is 2·66. It is fusible under the oxyhydrogen blow-pipe, forming a colourless glass, very plastic, and ductile. Being slightly soluble, in the gelatinous state, it is sometimes found in mineral waters. If a dilute alkaline solution of silex is decomposed by an acid, the liberated silex remains dissolved: but it is precipitated, by concentration: and is rendered insoluble, by evaporation to dryness. It is difficult to explain the great difference, between silex in the soluble and insoluble states. When it is combined with alkali, if the latter is relatively considerable in quantity, the silicate dissolves in water.

378. Silex, though an acid, does not redden litmus paper [19]: but it forms salts with oxides, disengaging carbonic, and even sulphuric acid—as when it decomposes the sulphate of soda, in crude potash, at a high temperature. The whole of the sulphuric acid will not be separated, in this case, unless resolved into sulphurous acid and oxygen, by the agency of carbon.

379. The composition of silicic acid is not quite certain. There is reason to suppose that it is SiO_3:—there may even be two compounds, one of them SiO_2, and the other SiO_3. A similar doubt exists, as to its other compounds.

380. Manufacture of Porcelain. Silex is a very important constituent of both porcelain, and glass: this will, therefore, be a convenient time to examine the manufacture of these substances.

The production of porcelain in China is so ancient, that its *commencement is* lost in the most remote antiquity. It

calcium, oxide of manganese, and oxide of iron. In other cases, common salt, thrown into the furnace which contains the porcelain to be glazed, is diffused, in vapour, through the different articles, by the very elevated temperature: and its sodium unites with silex, at their surfaces. Glass, and hydrochloric acid are formed, water being decomposed. $SiO_3+NaCl+HO=(SiO_3+NaO)+HCl$. Other substances, also, are employed for the same purpose. Enamel is a species of glass, containing silex, with the oxides of tin and lead:—the oxide of tin gives whiteness, and that of lead fusibility.

386. Porcelain is now very frequently used, for statues, groups, &c.: and often, when they are not large, with great success. If their size is too great, it is difficult, and indeed—as appears from the most successful examples to be seen in Dresden, &c.—impossible to bake them, without producing cracks, and other serious blemishes.

387. Manufacture of Glass. The discovery of the mode of forming glass is said, by Pliny, to have been made accidentally, by some Phœnician merchants, who, when cooking their victuals on the sand, placed lumps of soda to support the vessels over the fire. The soda and the sand, acted on by the heat, is supposed to have produced glass. But the temperature could not possibly have been sufficiently high to fuse these substances together.

388. Both Pliny and Strabo, give such accounts of the glass houses of Sidon and Alexandria, as show that the ancients were acquainted with the methods of cutting, grinding, colouring, and gilding glass. Nevertheless, it was, in ancient times, an extremely costly substance. Perfectly transparent vessels, were then very rare, and brought enormous prices. Nero gave £50,000, for two glass cups with handles. Glass has been observed, in windows at Pompeii: but it must have been rarely used for that purpose, until the third century:—and its general adoption did not take place until long afterwards.

389. A means of rendering glass malleable, is said to have been found out in the reign of the Emperor Tiberius; and again, in that of Louis XIII. But in both cases, punishment—in the former that of death—was the only *recompense* bestowed on the discoverers; and their secret

if it ever existed, died along with them. Pieces of glass, taken from an old pit twelve feet deep, were, indeed, found by Colladon to be flexible, and so soft that they might be cut with a knife. But they became hard and brittle, on being exposed to the air for a few hours.

390. Glass is essentially a combination of silicates, each of which, if used separately for the purpose, would be attended with certain inconveniences. Potash and soda—but particularly the former—render glass easy of fusion. Glass made with potash will bear to be remelted several times, without its alkali being driven off by the heat, &c., and its being, therefore, rendered less fusible. Continued heat, will drive away all the alkalies: and form a compound, similar to Reamur's porcelain. Soda communicates a bluish green tinge to glass, but increases its brilliancy. The silicates of potash and soda never crystallize; those of lime and the protoxide of iron do:—but their tendency to crystallization may be diminished, by silicate of alumina, and may be entirely prevented, by the addition of silicate of potash. Alumina, increases the difficulty of fusion; oxide of lead, produces an opposite effect. Two silicates, in combination, melt at a lower temperature than the mean of their fusing points. When glass is left a considerable time soft, without being melted, the silicates separate, and the less fusible, by crystallizing, render the glass opaque, and form the substance known as "Reamur's porcelain." If the silex, used in manufacturing glass, has not been made sufficiently fine—by heating it to redness, then throwing it into water, and afterwards carefully triturating it—white spots will appear. These are due to uncombined silex.

391. When carbonate of potash, or of soda, is employed in making glass, the carbonic acid is driven off by the mere application of heat; but [378] if sulphate of soda is one of the materials, carbon must be added, to decompose the sulphuric acid, and form carbonic oxide with some of its oxygen. If the mixture to be vitrified contains chloride of sodium, the latter is decomposed, by flame charged with moisture, hydrochloric acid and oxide of sodium being produced [385]: but some of the soda is wasted, as chloride of sodium *is volatilized* by a high heat.

392. The green colour, perceived in some kinds of glass, is due to the presence of black oxide of iron. A little peroxide of manganese changes this into peroxide; and, by losing some of its oxygen, is itself changed into protoxide. The small quantity of peroxide of iron, which results, will be sufficient to give only a very slight yellowish brown tint. Nitre would change the manganese back again to peroxide. If there is an excess of peroxide of manganese, it will become, at a red heat, sesquioxide, which imparts a deep amethystine red tint: a stick of wood thrust into the "metal," as the melted glass is called, would remove this colour, by taking oxygen from the manganese. Exposure to the air destroys the colour of bluish or greenish glass, by peroxidating the iron. But glass containing manganese becomes purple red in the same circumstances, and for a similar reason. If carbon is present in glass, as an impurity, it is banished by peroxide of manganese, which gives to it a portion of its oxygen. When the iron is peroxidized by arsenious acid (AsO_3), metallic arsenic is evolved in vapour. Bottles containing much alumina, are acted upon by tartaric acid, and spoil wine.

393. The principal kinds of glass are flint glass, crown glass, broad glass, bottle glass, and plate glass. *Flint glass*, one species of which is also called "crystal," derives its name from having been formerly made with flints—and probably, also, from its appearance. It is very beautiful, and has a high refractive power. It is employed very extensively in the construction of optical instruments. Its ingredients, like those of porcelain, and of the other kinds of glass, are united by different manufacturers, in different proportions. It sometimes consists of silex, soda—or potash—oxide of manganese, and oxide of lead. Caustic potash, carbonate of ammonia, &c., renders it extremely brittle, particularly when its surface has been scratched and roughened. Hence, bottles containing these substances occasionally fall in pieces, after being used for some time.

394. *Crown glass* is very hard. It consists of silex and potash—or soda: and, sometimes, other substances, to correct its impurities. It is frequently used, as window glass.

395. *Broad glass* is coarser than crown glass. It is

manufactured from soapboilers' waste, consisting chiefly of lime and silex, with chlorides of potassium and sodium, some caustic alkalies, and alkaline carbonates.

396. *Bottle glass* is made of any sea or river sand, lime—sometimes clay—and an alkali: and requires a high temperature, for fusion. It is an excellent material, for vessels intended to hold substances having corrosive properties.

397. *Plate glass* is manufactured from sand, lime, and potash, or soda—to increase its fusibility [390]; also, substances are applied to render it colourless. It is poured on perfectly smooth metallic plates; and, while fluid, is rolled into sheets. The bronze slab, used for this purpose at St. Gobin, weighs 50,000 lbs., and cost £4,000. The cylinder with which it is rolled often weighs several cwts.

398. It is curious that good specimens of the different kinds of glass, according to the most careful analyses, approximate very closely to the following formulæ:—

Flint glass, . .	$=6KO+9PbO+20SiO_3$.
Crystal, . . .	$=KO+2PbO+8SiO_3$.
White crown glass, .	$=KO+CaO+3SiO_3$.
Bottle glass, . .	$=KO+8CaO+2Al_2O_3+Fe_2O_3+8SiO_3$.
Plate glass, . .	$=2NaO+CaO+6SiO_3$.
Window glass, . .	$=3NaO+5CaO+12SiO_3$.

399. Glass requires to be *annealed*, that is, cooled down gradually to the temperature of the atmosphere; or it would, of itself, break into pieces. What are called "Rupert's drops" illustrate this in a very striking manner. They are formed of glass poured, when melted, into water: and if their larger end is broken, nothing remarkable occurs; but if their smaller, they fly into powder, with a loud noise. Annealing would prevent this. Badly annealed glass may be made to bear changes of temperature, by heating it as high as possible in salt water, or oil, and cooling it gradually.

400. The process of annealing, to be perfect, requires great care. The properties of light [opt. 208], enable us to detect unannealed glass. It may be known to be sufficiently annealed for chemical purposes, by its not breaking *with boiling water*. If it is acted upon, by water, or acids,

it is of little use in the laboratory. Distilled water, or hydrochloric acid, boiled in it for some time, should, when evaporated, leave no residuum.

401. The art of staining glass is very ancient. The Emperor Adrian received stained glass goblets, as a present, from the Egyptian priests.

Sometimes the glass is coloured through its entire substance; at others, only to a greater or less depth from the surface: porcelain is never coloured, otherwise than superficially. When glass is stained only on its surface, beautiful patterns, &c., may be produced, by grinding it off from parts which are intended to be colourless.

402. *Yellow.* A dirty yellow, is obtained by using charcoal; but if the quantity of this substance exceeds a certain amount the tint becomes brown. A bright yellow, is imparted by oxide of uranium; as this substance, however, generally contains traces of iron, there is a tendency to green, in the tint produced by it. Oxide of silver, or chromate of lead, also, will give a yellow.

403. *Blue*, is obtained with oxide of cobalt (CoO)—the tint being more intense, if the glass contains no lead.

404. *Green*, is produced by protoxide of iron; or, a more beautiful shade, by oxide of copper (CuO). A grass green, by sesquioxide of chromium (Cr_2O_3); and an emerald green, by oxides of copper, and iron.

405. *Red*, is obtained by using peroxide of iron—but the resulting tint is brownish; or by suboxide of copper (Cu_2O), which is ascertained to be the colouring matter of red glass, found at the villa of Tiberius, in the island of Capri. The tint, produced by it, does not make its appearance, until the glass has been cooled, and then reheated: the reason of which has not been clearly ascertained. The colour derived from this substance is of such intensity, that it is difficult to use a quantity so small, as not to render the glass opaque. A scarlet, carmine, rose, or ruby red, may be imparted by oxide of copper. Peroxide of manganese [392], gives an amethystine tint.

406. A *purple*, is produced by oxide of gold.

407. A *flesh colour*, by oxide of iron, and alumina.

408. *Black*, being the absence of all colour, cannot be *imparted* without destroying transparency; and it is gene-

rally obtained, by means of some tint which is so intense [405], that opacity results from it.

409. Mixed colours are often produced, by combining the substances that give the tints of which they consist.

410. *Gilding of glass.* Glass is gilt, by rubbing on it, with a brush, oxide of gold—precipitated from a solution of the chloride, by caustic potash—mixed with anhydrous borax, and then with oil of turpentine, or gum water. When heat is applied, the oil of turpentine evaporates, or the gum is burned off, and the borax melts—so as to fix the reduced gold firmly to the surface. A fine polish is produced, by the burnisher—the gold being at first dull, and of a yellowish brown colour.

411. SOLUBLE GLASS was known to the alchymist, Van Helmont. It is very frequently used, to deprive substances, impregnated with it, of their combustibility. When an excess of alkali is united with silex, the resulting glass [377] is soluble. If silex is fused with an excess of carbonate of potash, two atoms of silex combine with three of potash, and a very deliquescent glass is produced. When the solution of caustic potash is saturated with precipitated silex, and the solution is evaporated, a glass consisting of eight atoms silex, and three of potash, is obtained. This is more useful than the former, since it is not deliquescent; and, though soluble in hot, is nearly insoluble, in cold water. It is "soluble glass:" and may be economically obtained, sufficiently pure for ordinary purposes, by completely vitrifying in a crucible 15 parts powdered quartz, or pure sand, 10 parts potashes of commerce, and one part charcoal—to decompose the sulphuric, and carbonic acids. The impurities contained in the result, are separated by pulverizing, and exposing to the air: the salts, of which they consist, then attract moisture, and being easily removed by cold water, the residual glass is washed with that fluid. A dilute solution of this glass, is decomposed by the carbonic acid of the atmosphere.

412. Linen, &c., the fibres of which are coated with soluble glass, cannot be burned. For, when heat is applied, the glass melts around them, and excludes the air [163].

413. It is *sometimes* employed as a kind of paint—being

mixed with a variety of materials, and used to render woodwork incombustible. But, though it is very conveniently applied, in this way, it is difficult to find substances by which it is not decomposed. It answers, also, as a cement for porcelain vessels; and for many other purposes.

414. When chalk, or gypsum, is saturated with soluble glass, and exposed to the carbonic acid of the atmosphere, it is impregnated to a considerable depth with silex, and becomes nearly as hard as marble. Objects, therefore, consisting of these substances, may thus be rendered very durable, and capable of a high polish.

415. If ordinary glass contains too much alkali, it approximates to the nature of soluble glass; and its tendency to attract moisture, renders it unfit for electrical purposes [elect. 20].

416. Fluoride of Silicon:—*symb.* SiF_3; *equiv.* 77·93. It is obtained, by mixing together, in fine powder, fluor spar and sand—or glass, and heating the mixture with oil of vitriol, in a large vessel, as it swells up very much. The fluoride of calcium silex and sulphuric acid, give hydrated sulphate of lime ($SO_3+CaO+HO$) and fluoride of silicon. $3CaF+SiO_3+3(SO_3+HO)=3(SO_3+CaO+HO)+SiF_3$. It is by some considered to be SiF_2: and then, silicic acid being SiO_2 [379], $2CaF+SiO+2(SO_3+HO)=2[(SO_3+CaO)+HO]+SiF_2$.

417. It is supposed by many chemists, that, when the silex, fluoride of calcium, and sulphuric acid, are heated together, the fluoride of calcium first forms hydrofluoric acid and lime, water being decomposed. $CaF+HO=HF+CaO$. And that, then, the hydrofluoric acid, lime, and sulphuric acid form hydrated sulphate of lime, and fluoride of silicon, water being reproduced. $3(SO_3+HO)+SiO_3+3CaO+3HF=3(SO_3+CaO+HO)+SiF_3+3HO$.

418. Fluoride of silicon is a colourless, transparent gas: which must be collected over mercury, since it is decomposed by water. Even the moisture of the atmosphere changes it into white vapour, water being decomposed, hydrofluosilicic acid ($SiF+HF$) being produced, and silex disengaged. $4SiF_3+3HO=3(SiF_3+HF)+SiO_2$.

419. When it is intended to obtain *hydrofluosilicic acid in solution*, the gaseous fluoride of silicon is passed into a

vessel of water, on the bottom of which is some mercury, into which the tube, conveying the gas to be decomposed, dips. If the extremity of the tube were placed in water, it would soon be stopped up, by the silex which is disengaged. The latter may be removed, by straining through a fine linen cloth.

420. When a solution of hydrofluosilicic acid is heated, fluoride of silicon is evolved: and hydrofluoric acid, which would act on the vessel, if of glass [372], remains. If it is added to a solution containing potash, or barium, sparingly soluble fluosilicate of potash—or of barium—is precipitated. Hydrofluosilicic acid is, by some considered to be (SiF_3+HF); its composition, like that of the other compounds of silicon [416], not being yet determined, with certainty.

421. Boron,* *symb.* B; *equiv.* 10·90. It is obtained, by acting on fluoborate of potash (BF_3+HF), with potassium. The terfluoride of boron is decomposed, its fluorine uniting with potassium, and boron being set free. The same changes occur, as when silicon [373] is produced in a similar way.

422. Boron is a dark olive substance; it is a non-conductor of electricity; and is insoluble in water, and other neutral fluids. At a temperature of 600°, it forms, with oxygen, boracic acid. Also, when boiled with nitric acid, or ignited with the carbonate or nitrate of potash.

423. It forms, with chlorine, &c., compounds analogous to those of silicon, already mentioned. And the same uncertainty exists as to their nature. Some chemists believe that boracic acid is BO_3, while others consider it to be BO_2. Some believe chloride of boron to be BCl_3, while others describe it as BCl_2: and thus of the rest.

424. Compounds of Boron.—Fluoride of boron (BF_3), and hydrofluoboric acid (BF_3+HF) &c., are obtained in the same way as fluoride of silicon, hydrofluosilicic acid, [416, &c.]

* So called, from its being the base of boracic acid, found in borax (borate of soda $3Bo_3+NaO+10Aq$). The latter derives its name from *buruk*, an Arabian word signifying brilliant.

CHAPTER IV.

THE METALS. Their General Properties, 425.—Aluminum, 430.—Compound of Aluminum, &c., 433.—Antimony, 435.—Arsenic, 439.—Barium, 444.—Compounds of Barium, &c., 447.—Bismuth, 453.—Cadmium, 457.—Calcium, 461.—Compounds of Calcium, &c., 463.—Cerium, 469.—Chromium, 472.—Cobalt, 478.—Columbium, 484.—Copper, 488.—Compounds of Copper, &c., 492.—Didimium, 498.—Donarium, 499.—Erbium, 500.—Glucinum, 501.—Gold, 503.—Compounds of Gold, &c., 507.—Ilmenium, 510.—Iridium, 511.—Iron, 515.—Compounds of Iron, &c., 521. Steel, 524.—Lanthanum, 539.—Lead, 541.—Compounds of Lead, &c., 544.—Lithium, 551.—Magnesium, 555.—Manganese, 559.—Mercury, 565.—Compounds of Mercury, &c., 569.

425. THE METALS. THEIR GENERAL PROPERTIES.—The metals are opaque substances, conductors of heat, and of electricity; they have a peculiar and well-known lustre, termed "metallic;" and are all *positive* electrics, [gal. 60.] They differ extremely in their tenacity [mech. 31], their malleability, ductility, hardness, volatility, and density; and in the facility with which they combine with non-metallic elements. Their tenacity, is greatly injured by annealing. There is a difference between malleability and ductility: the metals which afford the finest wire, do not always give the thinnest leaves. Iron is more ductile than copper, but much less malleable. Some metals are found "native"—that is uncombined with other elements. Some are united with arsenic, with chlorine, iodine, sulphur, or an acid—but most usually with oxygen. Some have only one; others, several oxides. Some metallic oxides—as those of gold, silver, mercury, and platinum—may be reduced by heat alone: others require heat and a combustible—a stream of hydrogen, for instance, or charcoal. Some are reduced by deoxidizing *substances*: such as phosphorous acid (PO_3), which, added *to a solution* of oxide of mercury, sets the metal free, phos-

phoric acid (PO_5) being produced. Some, by another metal, as when mercury is precipitated from a solution of its nitrate, by means of metallic copper, nitrate of copper being left in solution; or, when copper is thrown down from a solution of one of its salts, by iron, which takes its place, and, forming a new salt, remains in the solution.

426. When an oxide is reduced, by heating it with fuel, the carbon of the latter unites with the oxygen of the former. If the oxide is in combination with carbonic acid, that acid must, first, be driven off by heat: since carbon will effect the reduction only of an oxide. If a metallic salt is strongly heated with carbon, the oxygen, both of the acid, and of base, is removed; and the elements, left behind, form a new combination:—in this way, sulphate forms sulphuret of lead. When a sulphuret is heated, in a current of air, the metal is oxidized: and both sulphurous and sulphuric acid are produced:—a portion of the latter is driven off, and the remainder unites with an excess of oxide. This process is termed "calcination."* If the residue were reduced by carbon, the result would be impure, on account of some sulphuret being formed, by deoxidation of the sulphuric acid. To prevent this, before deoxidation is begun, a proper amount of lime is added. The acid is taken away by the lime, which becomes first a sulphate, then, by the agency of the heat, a sulphuret, and floats on the metal as a glassy scoria. Other circumstances connected with this subject, shall be noticed as we proceed.

427. Metallic oxides are divided into those of the metals proper, as the oxide of gold: those of the alkalies, as soda: of the alkaline earths, as lime: and of the earths proper, as alumina. All the earths, except silex, are metallic oxides.

428. The metals have been variously arranged. By some chemists, in two classes, as follow:—

I. Those yielding alkalies, and earths. And
II. Those yielding neither the one, nor the other.

CLASS I. CONTAINS

1. The bases of the alkalies.—Potassium, sodium, and lithium.

* *Calx*, a cinder. Lat.

2. Bases of the alkaline earths.—Barium, calcium, magnesium, and strontium.
3. Bases of the earths.—Aluminum, glucinum, thorium, yttrium, and zirconium.

CLASS II. CONTAINS

1. Those which decompose water at a red heat.—Cadmium, cobalt, iron, manganese, nickel, tin, and zinc.
2. Those which do not decompose water at a red heat; and whose oxides are not reduced by heat alone.—Antimony, arsenic, bismuth, cerium, chromium, columbium, copper, lead, molybdenum, tellurium, titanium, tungsten, uranium, and vanadium.
3. Those which do not decompose water at a red heat; but whose oxides are reduced at that temperature.—Gold, iridium, mercury, osmium, palladium, platinum, rhodium, and silver.

429. They have also been divided into six classes, according to their comportment with sulphuretted hydrogen, &c., as follow:—

CLASS I. CONTAINS

Those whose oxides are not precipitated by sulphuretted hydrogen, hydrosulphuret of ammonia, or the alkaline carbonates.—Ammonium (?), potassium, sodium, and lithium.

CLASS II. CONTAINS

Those whose oxides are not precipitated, by sulphuretted hydrogen; but are precipitated by alkaline carbonates; and, under certain circumstances, as salts, by hydrosulphuret of ammonia.—Barium, calcium, magnesium, and strontium.

CLASS III. CONTAINS

Those whose oxides are not precipitated, by sulphuretted hydrogen; but which are precipitated, as oxides, by hydrosulphuret of ammonia.—Aluminum, cerium, chromium, glucinum, tantalum, titanium, thorium, yttrium, and zirconium.

CLASS IV. CONTAINS

Those whose oxides are not precipitated from their acid solutions, by sulphuretted hydrogen; but are entirely precipitated, as sulphurets, by hydrosulphuret of ammonia.—Cobalt, iron (protoxide, and sesquioxide), manganese (protoxide), nickel, uranium, and zinc.

CLASS V. CONTAINS

Those whose oxides are completely precipitated, from their solutions, whether acid, alkaline, or neutral, by sulphuretted hydrogen; their sulphurets being insoluble in alkaline hydrosulphurets.—Bismuth, cadmium, copper, lead, mercury, osmium, palladium, rhodium (sesquioxide), and silver.

CLASS VI. CONTAINS

Those whose oxides are completely precipitated, from their acid solutions, by sulphuretted hydrogen: but since their sulphurets are soluble in alkaline hydrosulphurets, not from their alkaline solutions.—Antimony, arsenic, gold, iridium, molybdenum, platinum, selenium (?), tellurium, tin, tungsten, and vanadium.

We, however, shall find it more convenient to examine the metals in *alphabetical* order. We shall notice, at the same time, a few of their more important compounds.

430. ALUMINUM:*—*symb.* Al; *equiv.* 13·63. It was discovered by Wöhler, in 1828; and is obtained in brilliant grayish coloured scales, by acting with potassium, on chloride of aluminum:—the chloride of potassium, which is formed, may be washed away, with water. A most intense heat is evolved; and the action is so violent, that it is not safe to carry on the process in vessels of glass. It is obtained more conveniently, and in comparatively large quantities, by the method of M. Deville, a French chemist. Chloride of aluminum is first prepared, by mixing calcined alumina with charcoal; then forming a paste with the mixture and oil, and baking it in an earthen crucible: afterwards breaking it in pieces of a convenient size, and

* Thus named, because a constituent of alum $[(SO_3+KO)+(3SO_3+Al_2O_3)]$.

placing them in a tubulated retort of earthenware—not glazed on the inside with lead; and, finally, the whole being introduced into a furnace, and heated to a dull red, passing a current of chlorine rapidly through—to first drive off the water, and then form the chloride, which is collected in a bell-glass receiver, having a socket fitting into the neck of the retort, and its open end luted to a funnel. The socket must be kept hot to prevent choking: and the carbonic oxide ought to be consumed during the process to prevent inconvenience from it.

The metal is obtained from the chloride, by means of the galvanic battery.

431. Aluminum is white, with a faint tinge of blue. It is so malleable, and ductile, that it may be formed into thin sheets, and fine wire, without annealing. It conducts electricity eight times as well as iron, and is slightly magnetic. It melts at 773° Fahr. It is not acted on by sulphuretted hydrogen, water, or oxygen, if not heated. Its specific gravity being only 2·67, iron is nearly three times, and gold nearly eight times as heavy. It does not clog the file, in working: but adheres to clean iron surfaces, when heated: and, from the little tendency it has to corrosion, it will be very useful for culinary purposes, if it shall be procured with sufficient economy.

432. Aluminum forms, with oxygen, sesquioxide (Al_2O_3; 51·26), termed alumina. With chlorine, sesquichloride (Al_2Cl_3; 133·67). With sulphur, sesquisulphuret (Al_2S_3; 75·26). With phosphorus, sesquiphosphuret (Al_2P_3; 121·22). And, with selenium, sesquiselenuret (Al_2Se_3; 146·15), &c.

433. Compounds of Aluminum, &c.—*Alumina* is the most remarkable of its compounds. It constitutes the chief parts of the ruby and sapphire: and is an indispensable ingredient in every kind of earthenware [381]. It owes its ductility to, and has a very strong affinity for water—which causes substances containing much of it to adhere to the tongue and lips. It has a powerful affinity, also, for colouring matter [139], and for woody fibre. When breathed upon, it has a peculiar smell, termed "argillaceous." This arises, partly from the presence of oxide of iron, and partly, *perhaps*, from its exhaling ammonia, which it has a great

tendency to absorb. Pipe-clay—which contains alumina—when moistened with caustic potash, will, even after several days, emit enough ammonia to restore the colour of litmus paper, that has been reddened by an acid.

434. *Tests for Alumina.*—Alumina is precipitated from acids, as a hydrate (Al_2O_3+3HO), by the alkaline carbonates; and by caustic potash, or soda, but it is re-dissolved by excess of the alkali. It is precipitated, also, by ammonia, and re-dissolved by great excess. When alumina is thrown down, as a hydrate, it carries along with it, some of the substances, by which it is precipitated; and is not freed from them, except by repeated washing. It loses water, if exposed to a high temperature, and [heat 70] contracts in bulk: but it becomes anhydrous, only at a white heat. Alumina is precipitated, as a white sulphuret, by hydrosulphuret of ammonia.

A mineral, containing alumina, when moistened with a minute quantity of the solution of nitrate of cobalt, acquires, before the blow-pipe, a beautiful blue colour.

435. ANTIMONY:*—*symb.* *Sb*; *equiv.* 129·20. It was discovered by Basil Valentine, in 1490; and may be obtained, from sulphuret of antimony, one of its most abundant ores—the *stibium* of the ancients—by heating it with "black flux."† The potassium of the potash, combines with the sulphur of the sulphuret, forming sulphuret of potassium: and its oxygen unites, first with the antimony, forming oxide of that metal, and then with carbon, forming carbonic oxide. The fused metallic antimony falls to the bottom, and may be poured into moulds.

436. Antimony is white, but approaching to a bluish gray. Its specific gravity, is 6·702. It is brittle. It fuses at 810°—or a little below redness; and is volatilized, by a white heat. It takes fire spontaneously, in chlorine. It becomes tarnished, by exposure to the air; and is covered

* From *anti*, and *moine*, a monk, *Fr.*—on account of the disagreeable effects produced with it, on some monks, by its discoverer.

† Formed, by throwing into an ignited crucible—by small portions at a time—a mixture, containing one part, by weight, nitre, and two parts cream of tartar (bitartrate of potash). The carbon of the resulting dark mass, when heated with metallic oxides, combines with their oxygen.

with a dark substance, by the continued action of air, and moisture.

437. Antimony forms, with oxygen, protoxide ($Sb O$; 153·20); peroxide or antimonious acid ($Sb O_4$; 161·20); and antimonic acid ($Sb O_5$; 169·20). The latter, a yellow powder, is obtained by acting on antimony with an excess of nitric acid, concentrating the solution—to drive off the excess of acid—and precipitating with water. It forms, with hydrogen, antimoniuretted hydrogen ($Sb H_3$; 132·20), which precipitates the salts of most metals—except those of copper, in which it differs from arseniuretted hydrogen. Antimony forms, with chlorine, protochloride ($Sb Cl_3$; 235·61), formerly called "butter of antimony;" bichloride ($Sb Cl_4$; 271·08); and perchloride ($Sb Cl_5$; 306·55). With bromine, a bromide—not well known. With sulphur, protosulphuret ($Sb S_3$; 177·2); sulpho-antimonious acid ($Sb S_4$; 193·2); and sulpho-antimonic acid ($Sb S_5$; 209·2), &c.

The oxide and protochloride form oxy-chloride—called, from the name of its discoverer, "the powder of Algarotti." It is obtained, by adding a considerable quantity of water to the chloride. Both are decomposed, and hydrochloric acid is set free. $4 Sb Cl_3 + 9HO = (Sb Cl_3 + 3 Sb O_3 + 3Aq) + 9HCl$. It becomes heavy and crystalline, after some time; but immediately, when the water employed is hot. If tartaric acid is present, or is added, the precipitate dissolves: which is not the case with the analogous precipitate formed by bismuth. The oxide and protosulphuret, form oxy-sulphuret ($2 Sb S_3 + Sb O_3$).

438. *Tests for Antimony.*—Antimony, in solution as protoxide, gives, with caustic potash, the alkaline carbonates, phosphate of soda, and with ammonia, a white precipitate—the oxide itself, soluble in caustic potash. With sulphuretted hydrogen, in acid solutions, and hydrosulphuret of ammonia, in all, an orange yellow precipitate—the hydrated protosulphuret, which is soluble in excess, in caustic potash, and in hydrochloric acid: and is distinguished from orpiment ($As S$), by not being volatile: and from bisulphuret of tin, by forming, along with zinc and sulphuric acid, antimoniuretted hydrogen. If the glass tube through which this gas is transmitted is ignited, the antimony will be reduced *at* the heated part, and will exhibit

a brilliant appearance; but, on passing dry sulphuretted hydrogen through the tube, it will become a yellow sulphuret: and the latter will be changed, by hydrochloric acid gas, into volatile chloride—which, being received into water acidulated with hydrochloric acid, may be precipitated with sulphuretted hydrogen. Metallic zinc, throws down antimony, as a black powder—and along with it, if nitric acid is present, some sesquioxide.

439. Arsenic:*—*symb.* As; *equiv.* 74·92. This metal was discovered by Brandt in 1733. It is found in nature, combined with other metals: and is generally procured, in roasting the ores of cobalt, and nickel. The arsenious acid, carried into the chamber intended for its reception, is purified by re-sublimation; and metallic arsenic is obtained from it, by heating it to redness, in a crucible, along with twice its weight of black flux [435]. The metal sublimes into a larger crucible, inverted for the purpose over the former, and is condensed in it.

440. Arsenic is white, but approaching to a steel gray colour. Its specific gravity, is 5·8843. It is extremely brittle: and it crystallizes in rhombohedrons [67]. It sublimes, without melting, at 356°; and its vapour has the smell of garlic. It is supposed, by Regnault, to be incapable of assuming the fluid state, on account of the point at which it boils under the pressure of the atmosphere, being very near that at which it fuses. As the point at which bodies liquefy is not affected by pressure, while that at which they boil is, increasing the pressure sufficiently would probably render arsenic fusible. By the action of the air, it gradually changes to a gray powder—the suboxide, supposed by some, to be a mixture of arsenious acid and metallic arsenic. It is rapidly oxidated, in nitric acid; it deflagrates, violently, in melted nitre; and burns spontaneously, with a beautiful blue flame, in chlorine.

441. Arsenic forms, with oxygen, arsenious acid (AsO_3; 98·92), called, "white arsenic," and "oxide of arsenic;" also arsenic acid (AsO_5; 114·92). With hydrogen protohydruret (AsH; 75·92) supposed to be metallic arsenic, in a finely divided state; and arseniuretted hydrogen (AsH_3; 77·92). With chlorine, chloride ($AsCl_3$; 181·33). With

* *Arsenicos, powerful. Gr.*; from its poisonous properties.

iodine, periodide ($As I_3$; 709·17). With bromine, bromide ($As Br_3$; 314·83). With sulphur, bisulphuret ($As S_2$; 90·92), called, also, "realgar;" sulph-arsenious acid (As_3; 122·92) [292] termed "yellow arsenic," and "orpiment;" and persulphuret ($As S_5$; 154·92), or sulph-arsenic acid, &c.

442. *Tests for Arsenic.*—Arsenic, in solution, gives, with sulphuretted hydrogen, and hydrosulphuret of ammonia, a yellow precipitate—sulph-arsenious, or sulph-arsenic acid. It may be easily distinguished, from the sulphurets of selenium, cadmium, tin, or antimony; for, when ignited, with twice its weight of black flux, in a hard glass tube, metallic arsenic sublimes into the *upper* part: and there is a smell of garlic, from some oxide being formed. Before testing, the solution must be rendered acid, by adding acetic, or hydrochloric acid, since the precipitate would be redissolved by free alkali. Nitrate of silver, causes in neutral, and ammonio-nitrate ($NO_5 + AgO + 2NH_3$), in acid solutions, a yellow precipitate ($As O_5 + 3AgO$, or $As O_5 + 3AgO$), soluble in dilute nitric acid, and in water of ammonia. Sulphate of copper produces in neutral, and ammonio-sulphate $[(SO_3 + NH_4O) + (NH_3 CuO)]$, in acid solutions, a yellowish green ($As O_5 + 2CuO$), or a greenish blue ($As O_5 + 2CuO + HO$), precipitate. Lime water, and the soluble salts of lime, give, with arsenious acid, a white arsenite ($As O_3 + 2CaO$).

443. Arsenic may be detected, likewise, by filtering the liquor supposed to contain it, acidulating it with sulphuric acid, and placing it in a flask, to which a small tube of hard glass has been attached. On introducing into the acidulated liquor, a piece of zinc, if arsenic is present, arseniuretted hydrogen will be evolved: and, when set on fire, will deposit metallic arsenic on a bit of glass tube, held over the flame. If the gas is produced, only in minute quantities, a part of the hard glass tube, through which it passes, is to be ignited: and the metallic arsenic will be deposited, *beyond* the heated portion. Arseniuretted hydrogen, may be distinguished from antimoniuretted, by the part of the ignited tube, in which the metal is deposited. Besides, arsenic is volatilized by heat, which is not the case with antimony. If the suspected fluid con-

tains both antimony and arsenic, they will be deposited in their respective portions of the tube—one at the heated part [438], and the other beyond it. Zinc, and sulphuric acid, sometimes contain arsenic: and it has been found in the human body, without having been administered as a poison. Hydrated peroxide of iron, is an antidote for arsenic—the resulting arsenite of iron not being poisonous.

444. Barium:*—*symb.* Ba ; *equiv.* 68·39. It was discovered by Davy, in 1807 : and is conveniently obtained from nitrate of barytes. When the latter is gently heated to redness, in a porcelain crucible, it melts, and is decomposed—the nitric acid giving off, in succession, each atom of its oxygen. When it has become nitrous oxide, it combines with the barytes ; but the resulting compound is decomposed, the last atom of oxygen—as also the nitrogen—being evolved, and pure barytes being left behind. To prevent the inconvenience, arising from the frothing up of the decomposing salt, the nitrate may be previously mixed with twice its weight of sulphate of barytes, in fine powder; and, after the process is finished, the barytes may be dissolved out, with hot water, from the sulphate—which is not changed. If the vapour of potassium is passed over the barytes, heated to redness, potash will be formed, and metallic barium will be set free. The latter may be dissolved out by mercury, and the mercury driven off, by heat.

445. Barium, is of a grayish white colour ; it is heavier than oil of vitriol. It fuses below a red heat: decomposes water rapidly—hydrogen being liberated, and oxide of barium being left in solution.

446. Barium forms, with oxygen, protoxide (Ba*O* ; 76·39), called also "baryta," and "barytes ;" and peroxide (BaO_2; 84·39). With chlorine, chloride, (Ba*Cl* ; 103·86). With iodine, iodide (Ba*I* ; 195·24). With bromine, bromide (Ba*Br* ; 148·36). With fluorine, fluoride (Ba*F* ; 87·25). With sulphur, sulphuret (Ba*S* ; 84·39), &c.

447. Compounds of Barium, &c.—*Barytes* (Ba*O*) may be obtained, by gently heating nitrate of barytes to redness in a porcelain crucible, until the escape of gas has

* *Barūs*, heavy. *Gr.* Because sulphate of barytes, on account of its great weight, was termed "heavy spar."

ceased. To prevent inconvenience from frothing, the nitrate may be mixed previously with twice its weight of sulphate of barytes in fine powder; and after the process, the resulting barytes may be dissolved out from the insoluble sulphate, by boiling with water.

448. *Nitrate of barytes* (NO_5+BaO) may be formed from native carbonate, by digesting with dilute nitric acid, and filtering the solution. The crystals obtained from the latter, are purified by recrystallization.

449. *Chlorate of barytes* (ClO_5+BaO) may be made, by passing chlorine through a solution of barytes in hot water: which produces chloride of barium and chlorate of barytes. The chloride of barium, is decomposed by nitrate of silver, which throws down chloride of silver, that may be removed by decantation, and leaves nitrate of barytes in the solution—from which chlorate of barytes may be precipitated, if the liquor is concentrated by evaporation.

450. *Chloride of barium* ($BaCl$), may be obtained, by dissolving the native carbonate in dilute hydrochloric acid. Carbonic acid is evolved; and chloride of barium crystallizes from the hot solution, in rhomboidal tables. This chloride precipitates carbonic, hyposulphurous, sulphurous, hyposulphuric, sulphuric, selenic, hypophosphorous, phosphorous, phosphoric, boracic, silicic, and hydrofluoric acids; also many metallic acids, from their neutral solutions.

451. *Tests for Barytes.*—Barytes gives, with carbonate of soda, a white carbonate (CO_2+BaO); with sulphuric acid, or a soluble sulphate, a white sulphate (SO_3+BaO) —insoluble in nitric, or hydrochloric acid; and with hydrofluosilicic acid, a white silicofluoride of barium (SiF_2+BaF). None of these precipitates are affected by water containing sulphuretted hydrogen.

452. The soluble combinations of barium are all poisonous: and the carbonate becomes so, on account of meeting, in the stomach, with hydrochloric acid, which changes it into a soluble compound. From this cause, fowl will not live where it is found among the gravel, &c.—on account of their habit of swallowing small pebbles, to aid the gizzard in triturating their food.

453. BISMUTH:* *symb.* Bi; *equiv.* 70·95. This metal

* *Weismuth*, white mother of silver. Ger.

was known to the ancients; and was described by Agricola, in 1530. It is obtained, from the rocks in which it is found, by pounding to a coarse powder, and igniting them :—the bismuth melts out.

454. Bismuth is white, with a shade of red; and has a crystalline structure. Its specific gravity, is 9·822. It is brittle, when cold; but it may be hammered into plates, when warm. It melts at 497°—or below redness. When heated to whiteness, it is volatile, and burns, the flame being of a bluish white. It is little affected by exposure to the air, at common temperatures :—it is, however, easily oxidated. Nitric acid acts upon it with great energy; but it is scarcely affected by sulphuric, or hydrochloric acid. If water is added to a solution of the nitrate ($12NO_5+4Bi_2O_3$), subnitrate ($3NO_5+3Bi_2O_3$) is thrown down as white powder, $3NO_5+Bi_2O_3$ being left in solution. Bismuth may be purified, by deflagrating some nitre upon it, when it is in a state of fusion: for its impurities, being more oxidizable than itself, float, as scoria, on its surface.

455. Bismuth forms, with oxygen, protoxide (BiO_3; 94·95), formerly called "magistery of bismuth;" peroxide (BiO_4; 102·95); and superoxide (BiO_5; 110·95), or "bismuthic acid." With chlorine, chloride ($BiCl_3$; 177·36); formerly called "butter of bismuth." With bromide, bromine ($BiBr$; 310·86). With sulphur, sulphuret (BiS_3; 118·95), &c.

The chloride of bismuth, like that of antimony [437], affords an oxychloride ($BiCl_3+2BiO_3+3Aq$), if water is added to it. Water is decomposed, and hydrochloric acid set free. This basic chloride is called "Spanish white," and "pearl white." It may be distinguished from the corresponding salt of antimony, by being insoluble in tartaric acid.

456. *Tests for Bismuth.*—Solutions of bismuth give, with the caustic alkalies, a white hydrated oxide (BiO_3+HO); and with the alkaline carbonates, a bulky white basic carbonate (CO_2+BiO_3). When carbonate of potash is used, some of it is carried down with the precipitate, and cannot be easily separated: when carbonate of soda, all the bismuth is not precipitated. Sulphuretted hydrogen, or hydrosulphuret of ammonia, throws down from neutral, or

acid solutions, a black sulphuret (BiS_3) soluble in boiling nitric acid. This precipitate is not formed, when an excess of hydrochloric or nitric acid is present, unless water is added. Chromate of potash, gives a yellow chromate (CrO_3+BiO), differing from chromate of lead by being soluble in dilute nitric acid, but insoluble in potash. Ferrocyanide of potassium gives a white, and ferridcyanide, a yellow precipitate.

457. CADMIUM:*—*symb.* Cd; *equiv.* 55·74. It was discovered by Stromeyer, in 1818. It is a very rare metal: and is obtained from the ores of zinc, with which it is associated. Silesian native oxide of zinc, contains from 1¼ to 11 per cent. cadmium. Dr. Wollaston separated it from the other metals, which are found along with it, by dissolving them: then placing the solution in a platinum vessel, and immersing in it a piece of zinc. The cadmium is reduced, and adheres so strongly to the platinum, that it may be washed with water, without separating. It is dissolved off, with dilute nitric acid; the nitrate is ignited: and the resulting oxide of cadmium (CdO) is exposed to a high temperature, in contact with carbon. Metallic cadmium passes over, in vapour. It may be conveniently obtained from a slightly acidulous solution of the ore in sulphuric acid, by diluting it with water, and acting on it with sulphuretted hydrogen, until the yellow precipitate is no longer thrown down. This precipitate, which is sulphuret of cadmium, is then dissolved in strong hydrochloric acid, the excess of which is driven off by heat. The result being dissolved in water, carbonate of ammonia is added in excess, to throw down carbonate of cadmium. This being removed from the solution—in which any copper or zinc present remains dissolved—is to be reduced, by heating with carbonaceous matter: the carbonic acid is driven off, and the oxide deprived of its oxygen. It is volatilized by the high temperature, and must be received in water.

458. Cadmium is white; it resembles tin, and takes a fine polish: its fracture is fibrous: it soils any thing like lead: is harder, and of greater tenacity than tin; and, like it, crackles when bent. It is very malleable, and duc-

* *Cadmia*, a name given in commerce, to the volatile matters *which rise from* the surface, when brass is made.

Its specific gravity, when melted, is 8·604; but, en hammered, 8·6944. It melts at 442°, or below red- s; and distils, at a temperature a little higher than that which mercury boils. It alters but little in the atmos- re, though it burns in it rapidly, emitting a yellow oke, which is without odour. It dissolves, slowly, in ute sulphuric: but rapidly, in dilute nitric acid.

459. Cadmium forms, with oxygen, oxide (C*d*O; 63·74). th chlorine, chloride (C*d*C*l*; 91·21). With iodine, iodide *d*I; 182·59). With sulphur, sulphuret (C*d*S; 71·74), &c.

460. *Tests for Cadmium.*—Cadmium gives with potash, l with ammonia, a white precipitate, the hydrated oxide *d*O+HO) soluble in ammonia: and, with the alkaline bonates, a white carbonate (CO_2+C*d*O). Carbonate ammonia must not be used, as the presence of ammoni- l salts prevents the complete precipitation of cadmium, a carbonate. Sulphuretted hydrogen, and hydrosul- uret of ammonia, throw down a bright yellow sulphuret *d*S), which is decomposed and dissolved, by boiling con- trated nitric acid. In solutions, containing a consider- e quantity of free acid, it is necessary to add water— order to throw down the cadmium, with sulphuretted lrogen. Metallic zinc precipitates cadmium, in the tallic state, as gray spangles.

461. Calcium:*—*symb.* C*a*; *equiv.* 20·0. It was dis- ered by Davy, in 1807; and is obtained from lime, in same way as barium, from barytes [444]. It is white tal, heavier than water—which it decomposes rapidly, e (C*a*O) being produced, and hydrogen evolved.

462. Calcium forms, with oxygen, oxide (C*a*O; 28), led "lime," and "quick lime;" also peroxide (CaO_2;). With chlorine, chloride (C*a*C*l*; 55·47). With ine, iodide (C*a*I; 146·85). With bromine, bromide *a*B*r*; 99·97). With sulphur, sulphuret (C*a*S; 36); ulphuret (CaS_2; 52); and pentasulphuret (CaS_5; 100). ith phosphorus, phosphuret (C*a*P; 51·32). With fluo- e, fluoride (C*a*F; 38·86), found in nature, as "Derby- re spar," &c.

463. Compounds of Calcium, &c.—*Lime* is the most

* From *Calx*, lime, *Lat.*:—because lime is an oxide of that tal.

remarkable of the compounds of calcium; and also the most interesting and important of the earths. It is obtained by calcining a carbonate—which, for the purposes of the laboratory, may be white marble. The heat drives off the carbonic acid. It has a very strong affinity for water [35]:—when exposed to the air, it takes moisture gradually from the atmosphere, and falls into a powder, which is a hydrate ($CaO+HO$). If dry, it has hardly any tendency to absorb carbonic acid; but, as a hydrate, a very strong one—the water being expelled by the acid. When the lime is half saturated, the carbonic acid is taken up by it with less rapidity [127].

464. *Carbonate of lime* (CO_2+CaO). Lime is very abundant, as a carbonate:—it constitutes enormous masses of limestone, chalk, and marble. It occurs, also, in the bones, teeth, and shells of animals, &c. It constitutes "calcareous alabaster," of which the oriental is the most beautiful kind. All of it has, probably, had an animal origin. Its production, from shells, can often be clearly perceived, in some kinds of limestone and marble. The latter differs from the former, &c., merely, in having been subjected to volcanic heat, under such pressure as prevented the carbonic acid from being driven off, at a temperature sufficient to melt the carbonate. It was known, long since, that carbonate of lime is capable of fusion, without being decomposed: for, in some of the ancient churches of England, marble pillars are found, which were evidently cast—the marks arising from the different portions of the mould having been carelessly put together, being distinctly visible. But the mode of casting marble was forgotten for ages: and even the possibility of fusing it was denied, notwithstanding the testimony of these pillars. The method has been, however, rediscovered—though, as far as we are able to learn, it is not at present used. Chalk is, probably, nothing more than carbonate of lime, precipitated from its solution in water containing carbonic acid. Whether the carbonic acid merely gives to that fluid a solvent power, which it does not possess without it, or the lime becomes a bicarbonate, has not been agreed upon by chemists:—those who hold the latter opinion, are most probably right.

465. *Sulphate of lime* (SO_3+CaO), may be obtained, by adding chloride of calcium to dilute sulphuric acid, and washing the precipitate well with water. It is found in nature, as "gypseous alabaster," ($SO_3+CaO+2HO$), a semi-crystalline substance, and "gypsum,"—from which, by calcination, is obtained "plaster of Paris." The latter is very important, on account of combining rapidly with water—so as to form a hard and solid compound. If the gypsum, during calcination, is exposed to a higher temperature than 300°, the sulphate which results, will not unite with that fluid; and is found in nature, as "anhydrite."

466. *Basic tribasic phosphate of lime* ($3PO_5+8CaO$) or the *earth of bones*, consists probably of two phosphates [$2(PO_5+3CaO)+(PO_5+2CaO+HO)$]. It is found, associated with fluoride of calcium, in bones, teeth, &c.; and may be obtained, by neutralizing the solution of any phosphate of lime with ammonia.

A brown mass, consisting of a phosphate of lime and phosphuret of calcium, is produced, when vapour of phosphorus is passed through a red hot tube containing lime:—if this is thrown into water, the latter and the phosphuret mutually decompose each other—phosphuretted hydrogen, which [325] inflames on reaching the surface of the fluid, and phosphite of lime, being formed.

467. *Chloride of calcium* ($CaCl$), may be obtained by dissolving white marble, or any pure carbonate of lime, in dilute hydrochloric acid. The solution should not have an acid reaction.

468. *Tests for Calcium.*—Sulphuric acid, and the soluble sulphates, produce immediately, in concentrated solutions of the salts of calcium, white precipitates (SO_3+CaO):—if the solutions are more dilute, the precipitate forms but slowly: and if very dilute, not at all, the resulting sulphate of lime being held in solution—unless alcohol is added. Oxalic acid gives, with salts of calcium, a white oxalate ($\overline{O}+CaO$), slightly soluble in excess;—ammonia increases the facility of precipitation, and the amount of precipitate. The oxalate, and phosphate of lime are dissolved, unchanged, by hydrochloric acid: and will be obtained again, by adding ammonia. Hence, if free hydro-

chloric acid is present in sufficient quantity, oxalic acid may give no precipitate, with lime.

The soluble salts of calcium give to alcohol a yellowish red flame, like those of strontia; but may be distinguished from the latter, by tinging the flame of the blow-pipe a brick colour.

469. CERIUM:*—*symb.* Ce; *equiv.* 46·05. This metal was discovered by Husinger, and Berzelius, in 1804: and is found in "cerite," a rare mineral. It may be obtained by calcining that substance, pulverizing, and dissolving it in aqua regia: then neutralizing the solution with caustic potash, precipitating oxide of cerium with tartrate of potash, changing the oxide to sulphuret—by heating it to redness for half an hour, along with three times its weight of sulphuret of potassium: and finally, converting the sulphuret into protochloride, by passing chlorine over it when raised to a high temperature in a glass tube, and, while the tube is hot, carrying off the volatile matters, by a current of hydrogen. Pieces of potassium are, after this, introduced into the tube, and heat is again applied:—the vapour of potassium, as it passes over the chloride, reduces some of it. The residue is then washed, with alcohol of a specific gravity 0·85, to remove the chloride of potassium, which has been formed. The brown powder that is left, and which consists of cerium, some of its oxide formed by the alcohol, &c., is to be pressed between the folds of blotting paper, and dried in vacuo.

470. The pure metal, which was obtained by Vanquelin, in very minute quantities, is white and brittle. It resists the action of nitric, but is dissolved by hydrochloric acid.

It forms, with oxygen, protoxide (CeO; 54·05); and peroxide (Ce_2O_3; 116·10). With chlorine, protochlorine (CeCl; 81·52); and perchloride (Ce_2Cl_3; 198·51). With sulphur, protosulphuret (CeS; 62·05), &c.

471. *Tests for Cerium.*—The salts of cerium have a sweet taste. They give, with potash, and ammonia, yellowish white precipitates, that become yellow by exposure

* From the planet Ceres. It will be seen that the discoverers of certain metals have given to them inappropriate, and sometimes very whimsical names.

to the air. They give no precipitate, with sulphuretted hydrogen; but white ones, with sulphuret of potassium, ferrocyanide of potassium, and oxalate of ammonia.

The discovery of lanthanum, and didimium—which are always found along with cerium—has rendered the received equivalent of the latter doubtful.

472. CHROMIUM:*—*symb.* $Cr.$; *equiv.* 27·99. It was discovered by Vanquelin, in 1797; and is found, combined with lead, or copper, as chromic acid; but more abundantly, in chrome iron ore (Cr_2O_3+FeO), as chromic oxide. To obtain it, the chrome iron ore is heated to redness with nitrate of potash, and the resulting chromate of potash, being dissolved out with water and filtered, is neutralized with nitric acid, and evaporated:—the salt it contains, is then removed by crystallization. A solution of the crystals, in water, being added to a solution of neutral nitrate of mercury, red chromate of mercury is precipitated. The mercury, and half the oxygen of the chromic acid, being expelled by a red heat, sesquioxide of chrome is left behind. Metallic chromium is obtained from this, by heating it intensely, in a crucible lined with charcoal, along with a mixture of plumbago and oil.

473. Chromium, is a grayish white metal. Its specific gravity is 5·9, or 6·0. It is brittle: and very infusible—being melted by a heat but little less than that of the oxy-hydrogen blow-pipe. It is scarcely affected by acids, except the hydrofluoric, in which it dissolves, hydrogen being evolved: it is very slightly soluble even in aqua regia.

474. Chromium forms, with oxygen, protoxide (CrO; 35·99); sesquioxide (Cr_2O_3; 79·98), the "green oxide;" chromic acid (CrO_3; 51·99). This compound, when strongly heated, gives off half its oxygen, and becomes oxide. It oxidizes organic substances, powerfully; and is, therefore, used in analyses. It is employed, also, in bleaching. Chromium forms, with oxygen, likewise, perchromic acid (Cr_2O_7; 111·98). With chlorine, chloride ($CrCl$; 63·46): sesquichloride (Cr_2Cl_3; 162·39). With fluorine, sesquifluoride (Cr_2F_3; 112·56), &c. It forms an oxychloride ($CrCl_3+2CrO_3$), called chlorochromic acid, &c.

* *Chrōma*, colour, *Gr.*:—from its tendency to form coloured compounds.

475. Sesquioxide of chromium, is remarkable for existing in two states, each of which has its own salts. As a hydrate (Cr_2O_3+5HO), which is soluble, though slowly, in dilute acids, and is of a bluish gray colour; and anhydrous, being then insoluble in dilute acids, but soluble slowly in boiling concentrated sulphuric acid. The salts of the hydrated oxide are green. They are soluble in hydrochloric acid; and some of them in water—the solutions, even when very dilute, being of a blackish green, and reddening litmus paper. The salts of the anhydrous oxide are of a bright violet colour; and are insoluble, in water, or the acids. Heat changes the soluble oxide into the insoluble; and many of its salts, into those of the insoluble, their colour being altered from green to violet. On the other hand, fluxing what have been thus altered, with carbonate of soda, reconverts them into those of the soluble oxide.

476. *Tests for Chromium.*—Sesquioxide of chromium, is precipitated from its combinations, as a bluish green hydrate (Cr_2O_3+HO), by caustic potash, and is redissolved by excess—the solution being emerald green; but it is precipitated by long continued boiling, or by the addition of sal-ammoniac. The same precipitate is thrown down by ammonia, and a small part of it is redissolved by excess, the solution being of a peach blossom red colour: the application of heat, reprecipitates what was redissolved.

477. Chromic acid gives, with the salts of lead, a yellow chromate (CrO_3+PbO), soluble in caustic potash, and changed to red, when heated with ammonia. And, with the salts of the black oxide of mercury, an orange precipitate (CrO_3+Hg_2O). When this, which is the subchromate, is heated to redness, mercury and oxygen are driven off, and sesquioxide is left behind [472]. It gives, with chloride of barium, a yellowish white chromate of baryte (CrO_3+AgO), soluble in nitric acid, and ammonia. With ferrocyanide of potassium, a grayish green precipitate. Chromic acid, whether in the free state, or combined, forms with sulphuretted hydrogen, oxide of chromium, sulphuric acid and water being produced, sulphur being precipitated, and the solution being changed to green. When no free acid is present, some hydrated oxide of *chromium* is thrown down, also, the precipitate being

greenish gray. Chromic acid, imparts a beautiful
to glass.

8. COBALT :*—*symb.* Co; *equiv.* 29·48. It was
vered by Brandt, in 1773; and is found in combina-
with arsenic, sulphur, and nickel. It resembles the
, very much, in its properties; and is entirely sepa-
from it, with great difficulty. Cobalt is obtained
the native arseniuret. For this purpose the ore is
ed in a current of air, to oxidize both the cobalt and
rsenic: the result, which constitutes the "zaffre" of
nerce, is dissolved in hydrochloric acid: and sulphu-
l hydrogen is passed through the solution, to preci-
the arsenic, and, along with it any copper present.
precipitate having been removed, the clear liquor is to
iled with a little nitric acid, to peroxidate the iron—
n, along with the cobalt, is precipitated by carbonate
tash; and the mixed precipitate being digested with
acid, soluble oxalate of iron, and insoluble oxalate
balt, are formed. The latter being removed, it is best
from the nickel it still contains, by the process of
g, which is as follows:—Much more hydrochloric acid
led than is sufficient to dissolve the oxalate, and more
enough cyanide of potassium than is required to re-
ve the precipitate first formed; after which, a little
chloric acid being dropped in, now and then, but not
gh to produce an acid reaction, the solution is kept
g for some time in a flask held obliquely, until the
chloric acid no longer causes the odour of hydrocyanic
o be perceptible. An excess of caustic potash is then
l, and, the mixture having been boiled for about ten
tes, the precipitated protoxide of nickel is removed.
filtered liquor is evaporated to dryness, with excess of
acid, and fused: the residual peroxide of cobalt is
ed with water, dissolved in hydrochloric acid, and
pitated again as oxalate. Oxalate of cobalt being
ed, carbonic acid is evolved, and spongy metallic
t remains behind.

9. The above process is easily explained. When

Kobold, an evil spirit, *Ger.* This name was given to it, by
erman miners, who did not know its value: and thought it
ourable in the presence of the other metals.

cyanide of potassium is added to the solution of ni
&c., cyanide of nickel ($NiCy$) is precipitated: and, b
redissolved by excess of cyanide, forms double cyani
nickel and potassium ($NiCy+KCy$). Since the solu
contains cobalt, along with free hydrochloric acid, cya
of cobalt ($CoCy$) is produced, and being redissolved
comes cobalti-cyanide of potassium ($Co_2Cy_6K_3$): whi
three atoms of nickel are present for every two of co
is changed into cobalti-cyanide of nickel (Co_2Cy_6
thrown down in the form of a bluish white precipitate.
there is *less* than that proportion of nickel, some cob
cyanide of potassium remains undecomposed, and in
tion: if there is *more*, some double cyanide of nickel
potassium remains undecomposed—until, being boiled
hydrochloric acid, it is changed into chloride of nickel,
chloride of potassium.

When the caustic potash is added in excess, the col
cyanide of nickel is decomposed, cobalti-cyanide of p
sium being reproduced, and protoxide of nickel p
pitated. $Co_2Cy_6Ni_3+3KO=Co_2Cy_6K_3+3NiO$.

When the filtered liquor is evaporated with nitric
the salts it contained are changed into nitrates: and
nitrate of cobalt is decomposed, by fusion, peroxid
cobalt being left behind.

480. Cobalt is of a reddish gray colour; its spe
gravity, is 8·538. When quite pure, it is not magn
It melts more easily than cast iron. It is not affecte
much by water, and the acids, as iron, and zinc—but
than nickel.

481. Cobalt forms, with oxygen, protoxide (CoO; 37
sesquioxide (Co_2O_3; 82·96); one complex oxide (C
equivalent to an atom of oxide, and an atom of ses
oxide; 120·44); and another (Co_6O_7, equivalent to
atoms of protoxide, and one of sesquioxide; 232
With chlorine, chloride ($CoCl$; 64·95). With sulp
sulphuret (CoS; 45·48).

The solution of chloride of cobalt is pinkish—unle
contains nickel, in which case it will be green. The
chloride, when dried, is blue: and is used to produce
"sympathetic ink"—which becomes visible on being he
If the chloride contains nickel, it becomes green, on b

heated: and is the substance employed in producing the representation of a winter and a summer scene, by means of the same picture. When the winter landscape is heated, the grass, &c., immediately becomes green.

482. *Tests for Cobalt.*—Cobalt, in solution, is known by giving, with caustic potash, a blue precipitate. The latter is a basic salt, which is changed by boiling with excess of potash, air being excluded, into a bright red hydrated protoxide (CoO+HO), soluble in carbonate of ammonia: but, boiled in contact with air, it becomes a dingy red mixture, consisting of hydrated protoxide, with some peroxide formed during the process. If the protoxide is ignited, in atmospheric air, it becomes one of the hydrated complex oxides. Ammonia gives the same blue precipitate—which is soluble in excess of the precipitant, and forms a solution, that is at first green, but is changed by the air to brown. Neither potash, nor ammonia, cause a precipitate, if there is much sal-ammoniac present; but the solution becomes brown, by the action of the atmosphere. The alkaline carbonates give, with solutions of cobalt, a red which, being boiled, becomes a blue precipitate. Phosphate of soda, gives a blue precipitate. Sulphuretted hydrogen, in alkaline solutions of the protosalts, and hydrosulphuret of ammonia, in neutral solutions, give a black sulphuret (CoS): in other cases, there is partial precipitation. Cyanide of potassium, gives a brownish white cyanide—redissolved by excess, and not precipitated by acids: ferrocyanide of potassium, a green precipitate, which gradually turns to gray: ferridcyanide of potassium, a brown precipitate.

483. The smallest quantity of cobalt, colours glass blue, before the blow-pipe. *Smalt*, a glass stained with cobalt, and ground extremely fine, is used for colouring porcelain, &c., and giving a slight shade to paper, linen, &c. When quite pure, it is a silicate of cobalt. The silex it contains, causes paper tinted with it to wear the nibs of pens rapidly. Chlorine, or oxygen, injures the colour produced by cobalt.

484. COLUMBIUM:*—*symb.* Ta;† *equiv.* 184·90. It is

* From Columbia, in America: on account of being first found, in a black mineral, supposed to have been brought from North America.

† Two *years after the* discovery of columbium, Ekeberg, a

called, also, *tantalum:* and was discovered by Hatchett, in 1802. It is a very rare metal: and is obtained, by a process similar to that used for procuring silicon [373]—which it resembles very much.

485. Columbium is a black powder, that becomes under the burnisher, an iron gray. In the pulverulent state [elect. 20], it is a non-conductor of electricity. It burns vividly, when heated in the air; but does not melt, at a lower temperature than that produced by the oxy-hydrogen blow-pipe. It is acted upon, only by hydrofluoric acid.

486. Columbium forms, with oxygen, binoxide ($Ta O_2$; 200·90); and columbic or tantalic acid ($Ta O_3$; 208·90), which, if hydrated, is a milk white, insipid, inodorous powder. With chlorine, terchloride ($Ta Cl_3$; 291·31), &c.

487. *Tests for Columbium.*—Tantalic acid, is separated from its solutions in the other acids, by sulphuric acid. It is thrown down, from its solution in hydrochloric acid, by tincture of galls, as an orange yellow powder: and is precipitated, unaltered, by the alkaline hydrosulphurets—sulphuretted hydrogen being evolved. It gives, with ferrocyanide, and sulphocyanide of potassium, white precipitates. It is soluble in caustic alkalies; and in the alkaline carbonates, at a boiling temperature—carbonic acid being liberated. When heated, it becomes anhydrous: and, while hot, is yellow, but, when cold, white:—in this state, it dissolves with difficulty, in acids, and alkalies. When tantalic acid is precipitated by sulphuric acid, and brought into contact with zinc and hydrochloric acid, it dissolves—the solution being at first blue, but afterwards brown. If the solution of a tantalate is acidified by hydrochloric acid, it dissolves—the solution being, at first blue, but afterwards brown. If the solution of a tantalate is acidified by hydrochloric acid, metallic zinc throws down from it a white tantalate.

Tantalic is distinguished from titanic acid, by the ease with which it is soluble in caustic potash.

488. COPPER:—*symb.* Cu;* *equiv.* 31·68. It was well

Swedish chemist, obtained a metal, which he called tantalum: but it was proved identical with columbium, to which it gave a symbol.

* From *cuprum*, its Latin name—derived from that of the isle *of Cyprus*, whence, anciently, it was obtained.

known to the ancients; and is found in abundance—often native, and, not unfrequently, crystallized. It is most commonly obtained as a native sulphuret:—copper pyrites ($Cu_2S+Fe_2S_3$) generally affords the copper of commerce. Since two metals are contained in this ore, and neither is volatile, it is necessary, in order to obtain one of them free from the other—besides the ordinary means for reducing sulphurets—to use certain precautions in the method employed. That the copper may not, during its reduction, be rendered impure, by the presence of iron, the process is stopped before that metal is reduced. But, as the reduction cannot be made to terminate, precisely at the proper moment, the resulting copper still contains some iron, and sulphur. It is calcined, to separate it from these—which, being more combustible than the copper, are first oxidized: and the separation is facilitated by sand—which forms silicate of iron. If the copper is kept too long in contact with the fuel, some of it combines with carbon; if it is not kept sufficiently long, it will contain suboxide:—and, in either case, it will be brittle, and unfit for many of the purposes to which it is to be applied.

489. Copper is obtained, also, in the metallic state, by precipitating it with iron, from its salts—held in solution by the water that runs from copper mines, &c. For this purpose, old iron is thrown into the liquid, and takes the place of the copper, which is set free.

490. Copper is of a reddish colour. The crystals which it forms when fused, or precipitated, are not the same as those found native. Its specific gravity is 8·9. It is very malleable, and ductile; and is the strongest of all the metals [mech. 31] except iron. It is an excellent conductor of heat, and of electricity. It melts, at 1996°: and is not volatilized, by heat. It is not affected by dry air; but in moist, it is gradually covered with a greenish hydrated basic carbonate $[(CO_2+CuO)+(CuO+HO)]$, which, though very thin, preserves the metal under it. Acids that, like the nitric, give off oxygen directly, dissolve copper [218]. The others, even including carbonic, dissolve it where it is in contact with the atmosphere, by which it is oxidized. In this way, poisonous salts are produced in culinary vessels, by the carbonic, acetic, and the fatty

acids. Water strongly impregnated with sulphuretted hydrogen, is an antidote for the salts of copper: also, large doses of sugar. Sulphuric acid, at a boiling temperature [306] dissolves copper—sulphurous acid being given off. Sometimes, when it is dissolved in nitric acid, a portion falls down, as oxide. If a red hot copper wire is drawn through cork, it will be rendered beautifully clean—the oxide which soiled it, having been reduced by the carbon; but it will be immediately tarnished again, by the air—oxide being reproduced.

491. Copper forms, with oxygen, red or suboxide (Cu_2O; 71·36). When copper is coated with this, either naturally or artificially, it has but little tendency to rust. It forms, also, black or protoxide (CuO; 39·68), called by the mineralogists, "copper black." Copper forms, with oxygen, likewise peroxide or cupric acid (probably CuO_2; 47·68). With chlorine, subchloride (Cu_2Cl; 98·83); and chloride ($CuCl$; 67·15). With sulphur, subsulphuret (Cu_2S; 79·36); and sulphuret (CuS; 47·68). With phosphorus, tri-phosphuret (Cu_3P; 126·36); and sub-sesquiphosphuret (Cu_3P_2; 157·68).

492. COMPOUNDS OF COPPER, &c.—Various compounds of copper with other metals are used in the arts. *Spelter*, a species of hard solder, consists of equal parts copper and zinc. It is applied to the surfaces which are to be joined, in grains, along with a mixture of borax and water: and is then heated intensely. *Brass*, contains about 16 parts of copper and 9 of zinc. *Pinchbeck*, 5 of copper and 1 of zinc. *Manheim gold*, which very much resembles the precious metal, consists of 3 parts copper, 1 of zinc, and a little tin. 2 parts copper and 1 of tin (Cu_4+Sn), form the best kind of *speculum metal*:—this alloy cannot be cut by steel, and crumbles when struck: it is perfectly white, and takes a fine polish. *Bell-metal*, which is brittle, consists of 3 parts copper and 1 tin. But 4 parts copper and 1 of tin form a compound which, if held between iron plates to keep it from warping, and plunged at a cherry red heat into cold water, is tough and malleable;—Chinese gongs, and cymbals, are made of this material—with sometimes a small quantity of nickel. 5 parts copper and 1 of tin, afford a very hard metal. *Bronze*,

consists of 9 parts copper and 1 of tin. *Gun-metal*, contains somewhat less tin:—and an inferior kind, is manufactured with lead, instead of all or a part of the tin. The surface of gun-metal is rendered very hard, by the tin having a tendency outwards. If moulds containing copper and lead are opened before they are cold, the lead will ooze out. But moulds containing brass, may be opened while red hot.

When an alloy is formed, the result may sometimes be considered as a new metal: it differs so much from its constituents. Thus, both copper and tin are malleable, and ductile; but gun-metal, formed by them, is neither. And, increasing the quantity of tin, the softer metal, increases the hardness of the compound. A third metal, sometimes changes the nature of the alloy. Brass containing a little lead is excellent for turning, but does not bear hammering. Soft solder that contains ever so little zinc, or has been used in soldering zinc, cannot be used in soldering lead, &c.—as it crumbles during the process.

493. *Black oxide of copper* (CuO), is extremely useful in chemical analyses. It may be obtained, by mixing pure copper scales with pure nitric acid in a porcelain capsule, so as to form a thick paste. When effervescence has ceased, the mass is to be gently heated, until it is dry; and the resulting green basic salt ($NO_5+3CuO+HO$) is to be raised to moderate redness, in a Hessian crucible, until no more nitrous acid vapours are perceived. The decomposition may be accelerated, and rendered uniform, by stirring with a clean glass rod. The pure oxide, which remains, must be levigated: and, as it would absorb moisture from the atmosphere, must be kept in a well-stopped bottle.

494. *Sulphate of the protoxide of copper* (SO_3+CuO) or blue vitriol, may be obtained by boiling metallic copper with oil of vitriol.

495. *Ammonio-sulphate of copper* [$(SO_3+NH_4O)+(NH_3CuO)$]. When excess of ammonia is added to a strong solution of sulphate of copper, crystals of ammonia-sulphate of copper separate, on cooling, if the liquid is merely poured from one vessel to another.

496. *Tests for Copper.*—The salts of the suboxide of

copper, are affected by reagents very differently from those of the protoxide:—but, in looking for copper, they are always changed into the latter. This alteration, is produced by mere exposure to the air: and so rapidly, that, when suboxide, thrown down by ammonia as a white precipitate, is redissolved by excess, the liquid—which is colourless—will become, at once, a blue solution of the protoxide.

497. Solutions of salts of the black oxide give, with potash, a bulky blue precipitate—the hydrated protoxide ($CuO+HO$), which, being boiled, becomes black anhydrous oxide. With caustic ammonia, or its carbonate, bluish, or green basic salts, which are soluble in excess—the solution being of a beautiful violet colour, and are similar, in constitution, to the ammoniacal sulphate [495]. With chromate of potash, a reddish brown precipitate, soluble in dilute nitric acid, and also in ammonia—the solution being green. With sulphuretted hydrogen, and hydrosulphuret of ammonia, a black sulphuret—slightly soluble in hydrosulphuret of ammonia, completely so in cyanide of potassium, and decomposed by boiling nitric acid. With cyanide of potassium, a yellowish green precipitate, soluble in excess of the precipitant. With ferrocyanide of potassium, a chocolate brown precipitate, insoluble in dilute acids, but decomposed by caustic potash: and with ferridcyanide of potassium, a yellowish green precipitate. Iron throws down copper in the metallic state, from its solutions; and zinc, in the same circumstances, becomes coated with it. The smallest quantity of copper, fused with borax, gives, in the oxidizing flame [101], a green glass containing the protoxide; but, in the reducing flame, a ruby-red glass, containing the suboxide. Flame is tinged green by copper.

498. DIDIMIUM:—*symb.* D. It is found, with peroxide of cerium, as peroxide—a brown powder. The salts of this metal are of a rose, or amethyst, colour. Its equivalent is not yet known.

499. DONARIUM:*—*symb.* Do, is a new metal, discovered by Bergemann, in a mineral from Brerig in Norway. It is obtained as a black powder, by treating the oxide

* From the God Donar. See note, page 164.

with potassium, immediately pouring off from it the alkaline solution, washing the residue with water, and separating it by filtration.

Donarium, in the state of a dry powder, assumes a metallic lustre when rubbed with agate. Its specific gravity, is 7·35. Thrown into flame, it burns with a reddish light, and yields red oxide. It is not acted on, by hydrochloric acid: but is slowly dissolved, in hot nitric. Nitro-hydrochloric acid forms the red oxide, and dissolves some of it. Sulphuric acid forms a sulphate, sulphurous acid being evolved. Donarium forms an oxide which belongs to the earthy bodies, and is precipitated by ammonia as a hydrate, which is first white, then yellow, and ultimately a yellowish red—having become anhydrous in the air, particularly if the temperature is slightly elevated. The oxide, as an hydrate, dissolves in all the acids; and with rapidity, if heated: when it is anhydrous, it is soluble by continued action with concentrated sulphuric acid, and the addition afterwards of a large quantity of water.

500. Erbium:—*symb.* Er. It has not been obtained in the metallic state. Its oxide was discovered by Mosander. If, on precipitating a solution of yttria, with an alkali, the latter is added gradually, and the precipitates are collected separately, and ignited, the first becomes orange—and is considered to be the oxide of erbium. But little is, however, as yet, known about it.

501. Glucinum:*—*symb.* G; *equiv.* 26·54. It was discovered by Wöhler, in 1828: and is a rare metal. It is found in the emerald, the beryl, and euclase or prismatic emerald. It may be obtained, by fusing beryl with carbonate of potash; then taking away the silex, by solution in dilute hydrochloric acid, and evaporating the result to dryness, after re-solution in water; precipitating the alumina, and glucina, with ammonia: dissolving the former, with a strong solution of carbonate of ammonia, and boiling the filtered solution: carbonate of glucina separates. The carbonic acid being driven off by heat, glucinum is obtained from the glucina which remains, in the same way as aluminum is obtained from alumina [430].

* *Glukûs*, sweet. *Gr.* From its salts, which have a sweetish taste.

Glucinum is a grayish black powder. It is not oxidized by the air, at ordinary temperatures; nor, whether hot or cold, by water. But, when heated to redness on platinum foil, it burns brilliantly, and forms glucina. It burns similarly, in oxygen, and chlorine: and in the vapours of iodine, and bromine.

It forms, with oxygen, an oxide (G_2O_3; 77·08), called glucina.

502. *Tests for Glucinum.*—Potash throws down, from solutions of glucinum, the earth glucina, which is redissolved by excess: but—unlike alumina, also precipitated and redissolved by potash—it is reprecipitated completely, by boiling in a dilute alkaline liquor, or in a solution of sal-ammoniac. Glucina is precipitated, but not redissolved, by ammonia. It is precipitated by the carbonates of potash, and soda, and redissolved by great excess. Unlike alumina [434], the precipitate it gives, with carbonate of ammonia, is redissolved by excess. It is precipitated, also, by phosphate of soda.

503. Gold:—*symb.* Au;* *equiv.* 91·33. This metal, has been known from the earliest antiquity. It is found only in the metallic state—either pure, or unalloyed: and is often picked up in the sand of rivers, being washed down from the mountains. It has been met with, in the county of Wicklow, both in very small grains, and in large masses:—one piece, obtained there, weighed eighteen, and another twenty-two ounces. At present, it is so abundant in California, &c., that the desire of finding it, has become a species of infatuation, which carries away vast multitudes from their homes and occupations, to that remote country. Gold is usually separated from the sand, &c., with which it is found mixed, by washing. The metal, on account of its weight, falls rapidly to the bottom of the vessel; and the lighter substances are decanted off. The process of washing is repeated, as often as it is considered necessary: after which, the particles of gold are picked out:—those which cannot be detected by the eye, being agitated with mercury, are dissolved by that metal, which is afterwards driven off by heat. Gold is separated from silver, by quartation [236].

* *Aurum*, gold. *Lat.*

504. Pure gold is of a reddish yellow colour:—that which is in ordinary use, owes its peculiar shade to the nature, and quantity, of the metal with which it happens to be alloyed. Its specific gravity is 19·5. It is extremely malleable, and ductile [12]: and so soft that, when used for coin, &c., it requires to be alloyed with copper, &c., to prevent its wearing out with great rapidity. Gold retains its brilliancy in air, and water, for any length of time. It fuses, at 2016°; and, when melted, emits a bluish green light—the same as that obtained by transmitting white light through gold leaf. It is soluble in aqua regia [358], and in a mixture of nitric and hydrofluoric acids.

505. The purity of gold is expressed in "carats."* A carat is the twenty-fourth part of the mass, whatever it may be. If twenty-two twenty-fourths are pure gold, it is said to be "twenty-two carats fine:"—this is the fineness of British gold coin. If eighteen twenty-fourths, it is "eighteen carats fine:" which is the fineness of watch cases, &c., and is the least pure that is stamped at Goldsmith's Hall.

506. Gold forms, with oxygen, protoxide (AuO; 106·33); binoxide (AuO_2; 114·33); and peroxide (AuO_3; 122·33), called, from its greater tendency to unite with acids, than oxides, "auric acid." With chlorine, protochloride ($AuCl$; 133·80); and terchloride ($AuCl_3$; 204·74). With iodine, protiodide (AuI; 225·18); and teriodide (AuI_3; 478·88). With sulphur, protosulphuret (AuS; 114·33); tersulphuret (AuS_3; 146·33), &c.

507. Compounds of Gold, &c.—*Peroxide of gold* (AuO_3), being employed in the electrotype processes, has become of considerable importance. It may be obtained by dissolving one part gold, in four of aqua regia: then evaporating the solution to dryness, and redissolving it in water:—some protochloride and metallic gold will be left. The solution is to be rendered strongly alkaline, with caustic potash; and, when it becomes turbid, is to be gra-

* *Carat* is the name of a fruit, obtained from an Abyssinian tree called *kuara*: it scarcely alters in weight after being gathered: and is used for weighing gold in Africa, and diamonds in India. A carat is considered equal to four grains, $74\frac{1}{16}$ of which make 72 grains troy.

abundant metal. It is found, sometimes, as a carbonate; at others, combined with oxygen, sulphur, or arsenic: and at others, with silex, alumina, &c.—as in clay iron stone. The latter, which is the most common of its ores, is decomposed, by mixing it with limestone and fuel, and applying an intense heat. The silicic acid of the ore drives off the carbonic acid of the limestone—a substance, between porcelain and glass, and consisting of silicates of lime, and alumina, which float on the metal, being produced. If carbon alone were used, the carbonic acid would be driven off; but the iron would form, with the silica and alumina, a glass, upon which the fuel would have no effect.

516. Pure or malleable iron, is obtained from cast iron (which is probably, about Fe_3C) by "puddling"—that is, burning off its carbon in a reverberatory furnace. The metal becomes less and less fusible; and there is ultimately obtained a granular mass, which is further united by heat: and is pressed together, with great force, by enormous hammers worked by steam. The impure iron is thus squeezed out, and the pure is welded together. The metal —which is kept at a proper temperature by the great pressure employed—is shaped into bars by a series of rollers.

Sometimes, the carbon is driven off as carbonic acid, by mixing the crude iron with oxide of iron. $Fe_3O_4+Fe_3C_2=Fe_{11}+2CO_2$.

If cast iron is left under water for a considerable time, the metal will become magnetic oxide, and be dissolved out: and the carbon will preserve all the original details.

517. Pure iron is brilliant, and of a bluish white colour. Its specific gravity, is 7·788. It is soft, flexible, ductile, and malleable. It requires an enormous temperature to melt it. But it is "welded," at a white heat: the surfaces being united by an incipient fusion—which is prevented, however, by the presence of a small quantity of copper, lead, &c., in the fire by which it is heated. Most other metals, like ice, melt without previously softening. It is not oxidated, in dry air; but it is peroxidated, when burned in oxygen—some of the oxygen being, however, driven off, by the high temperature. It dissolves, rapidly, in *sulphuric, nitric*, &c., acids.

518. Iron, in the form of a long wire, is not acted on by nitric acid having a specific gravity of 1·35, if one of its ends has been ignited, and, when cold, plunged, before any other part of it, into the acid. Also, if platinum and iron wires are fastened together, and the platinum is plunged first into the acid, the iron will be rendered passive. The same effect will be produced, if the platinum is first plunged in, and the iron is then put in contact with it, the platinum being afterwards removed; also, if the iron wire is made the positive pole of a battery [gal. 76]; or if it is put in contact with a wire already passive, and the latter is then withdrawn. The passive iron does not unite with oxygen, even at the pole of a battery: it does not rust, nor precipitate metallic copper [489] from its solution. Iron is not the only metal which may be rendered passive.

519. It is not certain that iron decomposes water, at ordinary temperatures, unless an acid is present. But, even carbonic acid will enable it to do so: hence, the carbonic acid of the atmosphere causes it to form "rust," which is a carbonate. Rusting is prevented by immersing the iron in a solution of caustic potash, lime, or soda: or by covering it with hydrate of lime. This arises, it is likely, from the carbonic acid being absorbed by these substances. At a red heat, iron decomposes water rapidly. It is scarcely ever found altogether free from carbon: hence, the hydrogen evolved by it [181] not being pure, is not inodorous.

520. Iron forms, with oxygen, protoxide (FeO; 36): peroxide (Fe_2O_3; 80) or "red oxide:" and combinations of these—as the ferroso-ferric or black magnetic oxide ($Fe_3O_4 = FeO + Fe_2O_3$), which is found native in abundance. It forms, also, ferric acid (FeO_3; 52). It forms, with chlorine, protochloride ($FeCl$; 63·47); and perchloride (Fe_2Cl_3; 162·41). With iodine, protiodide (FeI; 154·85): and sesquiiodide (Fe_2I_3; 436·55): With bromine, protobromide ($FeBr$; 107·97): and sesquibromide (Fe_2Br_3; 295·91). With sulphur, protosulphuret (FeS; 44); sesquisulphuret (Fe_2S_3; 104); magnetic sulphuret, found native, as "magnetic pyrites" ($Fe_3S_4 = FeS + Fe_2S_3$); bisulphuret (FeS_2; 60), the "iron pyrites" of mineralogists. With fluorine, *protofluoride* (FeF; 46·86); and perfluoride

Fe_2F_3; 112·58). With carbon, compounds the constitution of which is not, as yet, certainly known, &c.

521. Compounds of Iron, &c.—*Oxides of iron.* The protoxide is remarkable for its tendency to absorb oxygen. The peroxide is familiar to mineralogists as a natural product, under the name of "red hematite." It causes the red colour of clays; and is formed, at chalybeate springs, by decomposition of carbonate [195]. It is important, as an antidote for arsenic [443]: and may be prepared, as a hydrate, by dissolving together one part chlorate of potash, fourteen parts crystallized protosulphate of iron, and sixteen parts crystallized carbonate of soda: then washing the precipitate well. Black magnetic oxide is nearly identical with the ferruginous scales obtained in a smith's forge, and with the common loadstone: and is always produced, when iron is heated to redness, in atmospheric air. It causes the dull green colour of bottle glass.

522. *Protosulphate of iron* ($SO_3 + FeO$), may be made, by digesting iron wire in dilute sulphuric acid [180].

523. *Sulphuret of iron* (FeS), may be conveniently obtained, by raising a nail-rod, &c., to a white heat, in a forge or other intense fire: and then bringing it in contact with cane brimstone, over water. The sulphuret of iron fuses, as it is formed, and drops into the water: whence it is to be taken, dried, and placed in a bottle—which must be well stopped, to prevent the iron from absorbing oxygen, to which it has a great tendency. Protosulphuret of iron sometimes takes fire spontaneously in coal mines, when moist, on account of this strong affinity for oxygen.

524. Steel differs from "pig metal" [516], as commercial cast iron, is called, by having a smaller quantity of carbon. Cast iron contains about six parts in one hundred, carbon; but steel, sometimes, not more than one in four hundred. Also, the specific gravity of steel is higher.

Steel may be formed, either by leaving a sufficient quantity of carbon in combination with the iron; or, by afterwards adding it. The latter process is called "cementation" [73]. Iron has been converted into steel, by acting upon it when at a high temperature, and in an air-tight vessel, with coal gas. There are various kinds of steel—

525. Blistered steel, is made by placing alternate layers

consisting of iron bars and charcoal, in troughs of firestone: and arranging them in a furnace constructed for the purpose, the heat being applied for seven or eight days. When the bars are taken out, they are found to be covered with blisters, and have become steel. Blistered steel, exposed to a tilt hammer, which strikes about 700 blows in a minute, is increased in tenacity, and solidity; and is termed *tilted steel.*

526. *Shear steel,* so called, because the person who first made it, was in the habit of stamping it with the figure of a pair of shears, is formed by breaking up bars of blistered steel, then placing the fragments in a reverberatory furnace, and, when at a welding heat, uniting each bundle of pieces into one, by a large hammer. The process being repeated.

527. *Cast steel,* is obtained, by breaking blistered steel into small portions, and putting them, without any admixture, into crucibles. The latter are covered with lids, and placed—imbedded in coke—in a furnace, where they are kept intensely heated, for four or five hours. The steel having melted, it is then poured into moulds: and is afterwards finished, by hammering, and rolling.

528. Cast steel, is excellent for cutting instruments; but unlike the other kinds, it cannot—without being altered in constitution, and deteriorated—be joined, by welding, to iron, &c.

529. Steel combines with other metals. It is greatly improved, by the 500th of its weight, silver. If it contains the 100th part of its weight, platinum, it is not so hard as that made with silver: but it is more tough. Steel combines with gold, &c.: and it forms excellent compounds, with rhodium, iridium, and osmium:—but, from the scarcity of these metals, they are not often used. Acids, act very violently on the alloys of steel, formed with platinum, &c.; which is probably due to the production of galvanic circles [gal. 16]. Pure iron, with three per cent. iridium or osmium, affords a steel, not so liable to rust as the common kind.

530. *Damascus steel.* Wootz or Indian steel, is the crude material of Damascus sword blades. It has a "damasked," or waved appearance: and has been successfully imitated in Austria, and Prussia, by welding pieces of iron and steel together. Sword blades, made of

this material, have been struck against iron, without breaking—or even having their edges injured. Steel bars, containing within them a core of iron, are often used in the formation of taps for making hollow screws [mech. 242], &c. This combination possesses all the tenacity of iron: and, at the same time, the strength, and other advantages of steel. It is not liable, in hardening, to fracture, when plunged, at a high temperature, into cold water. Those, only, who are in the habit of working in metals, can appreciate its utility.

531. *Case hardening*, is a process by which the exterior of iron articles, such as fire irons, &c., is changed into steel. This is effected, superficially, by dipping them into a saturated solution of yellow prussiate of potash: or, when they are heated to redness, sprinkling them with powdered ferrocyanide of potassium. But, effectually, by heating them to redness, for some time, in close iron vessels, along with carbonaceous substances; and then plunging them into water.

532. Steel is *hardened*, by heating it to a cherry red, and dipping it in cold water. If it is not raised to the proper temperature, the object will not be attained: when but moderately hot, it is softened by water. If the steel, in hardening, is heated too much, it will be burned: and then it becomes valueless, for most purposes.

533. Steel plunged into water, at an elevated temperature, is made exceedingly hard, but at the same time, extremely brittle. Hence, in many cases—as when it is to have a fine edge, &c.—it requires to be "taken down" or "tempered." For this purpose, a portion of its surface being brightened, it is heated by being placed on red hot iron, &c., until the part, which has been cleaned, assumes a hue indicating the required temper. Sometimes, only the extremity of the steel is dipped in the water: and a portion, which is left very hot, serves to take down the rest: after which the whole is plunged into the fluid. When the steel is good, its surface becomes sufficiently clean, of itself, to show the proper tint.

534. During the process of tempering, the part which is cleaned becomes, at first, straw coloured, then pink, &c., *and finally* blue. These colours indicate successively di-

minishing degrees of hardness: and are selected, according to the purposes for which the instrument is intended. Sometimes, a bath of oil, or of fusible metal [heat 106], &c., is used to give the proper temperature. Or, the article is "blazed off"—that is, covered with grease, and heated, until it begins to blaze: the steel is then immersed in water. When the edge can be made so strong, that it is not liable to break, tempering is unnecessary, and the instrument, being left as hard as possible, will last for a long time without requiring to be repaired. It is worthy of notice, that the same angle does not answer for tools, intended to cut different metals. The cutting edge, for brass is 90°: but for iron, it is 60°.

535. The following are the tints, corresponding with the temper, given to various articles—

Very faint yellow, for lancets.
Pale straw, for razors, and surgical instruments.
Full yellow, for pen-knives.
Brown, for scissors; and for chisels intended to cut iron.
Brown with *purple spots*, for axes, and plane irons.
Purple, for table knives, and large shears.
Bright blue, for swords, and springs.
Full blue, for fine saws, daggers, &c.
Very dark blue, for hand, and pit saws. This is the lowest temper. Springs, &c., lose their elasticity, but not their hardness, by being polished:—it is restored, however, by heating over a clear fire, or in the flame of alcohol, &c.

536. Pig iron, after being cast in moulds, is rendered malleable, by taking away some of its carbon. This is effected, by heating it, when placed in alternate layers with substances having an affinity for that element. In this way, the advantage of casting from patterns, and, at the same time, the tenacity of wrought iron are secured. The metal produced is not, indeed, of a superior kind; but it answers very well for many purposes.

If a blast of atmospheric air is forced from a number of nozzles, into crude or pig iron in a state of fusion, the combustion of the carbon, which is in combination with the iron, will not only keep the metal in a fluid state, but will produce an extremely high temperature: and the

escape of the resulting carbonic oxide and carbonic acid will cause the mass to boil violently. And it has been recently asserted that, in this way, steel, and pure malleable iron, may be produced from the crude metal in a much shorter time, and at a much less expense, than by the ordinary method. Some, however, deny that the result is steel, or iron, of *good* quality: and a sufficient number of experiments have not yet been made, to decide the question.

537. *Tests for Iron.*—The proto-salts of iron have a greenish colour: and, by absorbing oxygen from the atmosphere, are changed into salts of ferroso-ferric oxide [520]. Salts of the protoxide give, with potash, or ammonia, a whitish hydrate of the protoxide ($FeO+HO$), which soon turns green, and ultimately brown red. The precipitation, by potash, is impeded, and that, by ammonia, altogether prevented, if ammoniacal salts are present. Acid solutions of the protoxide, are not precipitated at all, by sulphuretted hydrogen: neutral solutions, with weak acids, but imperfectly; alkaline solutions, perfectly—a black sulphuret (FeS) being produced. Hydrosulphuret of ammonia precipitates, from all solutions of the proto-salts, a black sulphuret (FeS), which soon becomes brown, and is soluble in nitric, or hydrochloric acid, but insoluble in alkalies, or alkaline sulphurets. Ferrocyanide of potassium throws down, in solutions of the proto-salts, a bluish white ferrocyanide of potassium and iron ($2FeCy_3+K+3Fe$)—which, by absorbing oxygen, becomes Prussian blue ($3FeCy_3+2Fe_2$), all of the potassium, and one atom of iron for every three atoms of the compound, being oxidized. This change is effected instantaneously, by nitric acid, or chlorine. Ferridcyanide of potassium gives, with salts of the protoxide, a blue precipitate—the ferridcyanide of iron ($2FeCy_3+3Fe$). Sulphocyanide of potassium, has no effect on solutions of salts of the protoxide which are quite free from peroxide.

538. The persalts of iron, have a more or less reddish colour. Compounds of the peroxide give, with potash, or ammonia, a bulky reddish brown precipitate—the hydrated peroxide (Fe_2O_3+HO), which is insoluble in salts of ammonia. With tannic, or gallic acid, a deep violet, or even *black*—the tannate or gallate of iron. Peroxide, in either

its acid or neutral solutions, is decomposed by sulphuretted hydrogen—water, and protoxide, being formed, and sulphur deposited. $Fe_2O_3+HS=2FeO+HO+S$. Hydrosulphuret of ammonia, precipitates the black protosulphuret, from neutral solutions of the per-salts—the peroxide being first changed by the re-agent into protoxide. Ferrocyanide of potassium, produces the precipitate of Prussian blue *at once*, with solution of the salts of the peroxide. Ferridcyanide of potassium, merely deepens the colour of solutions of the peroxide. Sulphocyanide of potassium, gives a most beautiful blood red colour to solutions containing the peroxide. It is due to the formation of sulphocyanide of iron ($Fe_2+3C_2N.S_2$), a compound which is found in the blood [173]. This test will enable us to detect the most minute quantities of iron.

The tests for salts of the sesquioxide are so decided, that, before looking for iron, it is usually peroxidized, if not so already:—this is effected, by boiling the solution with a little nitric acid.

Borax, or phosphate of soda and ammonia, forms, with salts of iron, in the oxidizing flame, dark red buttons—which, in the reducing flame, become bottle green, on account of the peroxide being changed to magnetic oxide. But these colours disappear, to a greater or less extent, on cooling—particularly with the phosphate of soda and ammonia.

539. LANTHANUM:*—*symb.* L; *equiv.* 48. It was discovered, by Mosander, that, if the protoxide of cerium is changed into peroxide, by calcination, a portion of the result still dissolves, in dilute nitric acid. And he found this portion to be, in reality, the oxide of a metal which he termed "lanthanum."

540. *Tests for Lanthanum.*—The protoxide of lanthanum has a slightly alkaline reaction. It gives white precipitates, with the caustic alkalies, and the alkaline carbonates.

541. LEAD:—*symb.* P;† *equiv.* 103·73. This metal was known to the ancients. It is found in combination with a variety of substances. But, for the purposes of commerce, it is obtained from "galena," a native sulphuret,

* *Lanthano*, I lie hid. *Gr.* † From plumbum, lead. Lat.

by exposing it, at first, to a moderately high heat, in a reverberatory furnace; then, after about half of it has become sulphate of lead, mixing it well, and, the temperature being rapidly raised, fluxing the whole. Metallic lead, and sulphurous acid, are the results. $(SO_3+Pb\dot{O})+Pb\dot{S}=2Pb+2SO_2$. The lead, so obtained, generally contains silver, iron, and copper.

542. Lead is of a bluish white colour. It is very brilliant, but soon tarnishes in the air—and is then protected from further action, by the coating formed upon it. Its specific gravity, is 11·44. It is very soft, flexible, and inelastic. It is ductile, and extremely malleable—but less tenacious than other ductile metals. It melts at 612°, a heat below redness, and contracts in cooling. Water containing atmospheric air oxidizes it rapidly—scales of carbonate of the protoxide being formed, with the oxygen and carbonic acid of the air. Hence, water that is kept in leaden cisterns may become poisonous [270]. But the presence of saline matters retards, or prevents, the action of the air, by forming a coating of insoluble compounds of lead. The more insoluble these are, the better their preservative power:—the three thousandth part phosphate of soda, or iodide of potassium, in distilled water, prevents any action whatever. Spring water, on account of the salts contained in it, has very often not the least effect on lead; and may, therefore, be safely drank from leaden pipes, or cisterns. Lead is scarcely affected by sulphuric, or hydrochloric acid, except at high temperatures. It is not corroded by the vegetable acids: although, in some instances—as happens with copper [490]—their presence accelerates the absorption of oxygen from the atmosphere. It is rapidly dissolved by nitric acid.

543. Lead forms, with oxygen, suboxide (Pb_2O; 215·46); protoxide ($Pb\dot{O}$; 111·73); red oxide (Pb_3O_4; 343·19); peroxide ($Pb\dot{O}_2$; 119·73). With chlorine, chloride ($Pb\dot{C}l$; 139·20), called, on account of assuming the appearance of horn, when heated "plumbum corneum,"* and "horn lead." With iodine, iodide ($Pb\dot{I}$; 230·58). With bromine, bromide ($Pb\dot{B}r$; 183·70). With sulphur, sulphuret ($Pb\dot{S}$; 119·73). With fluorine, fluoride ($Pb\dot{F}$; 122·59), &c.

* Horny lead. *Lat.*

544. COMPOUNDS OF LEAD, &c.—Various compounds of lead with other metals, are used in the arts. *Type metal* consists of 3 parts lead, and 1 antimony. *Pewter*, of which almost all foreign tin may be considered as a species, consists of tin and lead; and the better kinds, of tin with antimony and bismuth, and but little lead. *Soft solder* is composed of from 2 parts tin and 1 lead, to 1 part tin and 3 lead. A compound, containing equal parts of both, answers well for joining tinned iron, copper, &c. The larger the amount of tin, the more fusible the solder;—the finer kinds, melt at about 360°; and the coarser, at about 500°. Resin, &c., causes the solder to adhere to the metal, by preventing oxidation, or removing the oxide; a solution of chloride of zinc, or of sal-ammoniac, facilitates the union still more. Tin foil wetted with a strong solution of sal-ammoniac, answers well for fine joints in brass.

545. *Oxides of lead.*—The gray film, which is produced on the surface of melted lead, is *protoxide*. When this is exposed to heat and air, until it becomes of a uniform yellow colour, it is called "massicott"—and, if it is partially fused by heat, "litharge."

The acidity of weak wines is sometimes nefariously corrected by litharge, which, with the acetic acid of the wine, forms acetate of lead—called, from its sweet taste, "sugar of lead." Sulphuretted hydrogen will, at once, indicate the presence of the lead. Burgundy, and other wines containing tartrate of potash, cannot hold lead in solution—tartrate of lead being insoluble. The effect of acetate of lead, may be averted by a plentiful dose of epsom salt (sulphate of magnesia), or glauber salt (sulphate of potash); insoluble sulphate of lead being produced by them. The poisonous action of acetate of lead has been found to be neutralized, also, by sugar. The protoxide readily unites with earthy substances, forming with them a colourless glass: and it is the base of all the salts of lead.

Red oxide, the "minimum," and "red lead" of commerce, consists probably of two atoms protoxide, and one peroxide. Digested with nitric acid, it is decomposed into protoxide, and peroxide—the former being dissolved, and the latter being left behind as an insoluble powder.

The brilliancy of red lead, is sometimes impaired by excess of protoxide: which may be removed, by boiling in a solution of neutral acetate of lead.

Peroxide, if heated to redness, is changed into protoxide—oxygen being evolved.

546. *Ceruse* or the "white lead" used us a paint, is one of the most important of the compounds of this metal. It is a combination of basic carbonates, in variable proportions; and is made, by exposing sheets of lead to fumes arising from vessels containing weak vinegar. The lead being oxidized by the oxygen of the atmosphere, a basic acetate is first produced. This is changed, by the carbonic acid of the atmosphere, into basic carbonate, and neutral acetate. The latter, combining with a new portion of lead, again forms basic acetate; and is again decomposed as before. And thus, a small quantity of acetate may form an indefinitely large one of ceruse. The process is greatly improved, by exposing a mixture containing well-ground litharge, and one per cent. acetate of lead to the carbonic acid evolved in a brewery, &c.

547. *Neutral acetate of lead* ($\overline{A}+Pb O$), may be obtained, sufficiently pure, by dissolving the best commercial sugar of lead in distilled water.

548. The soluble salts of lead—but more especially the carbonate—and its oxides, often produce the most disastrous consequences, although introduced into the system, by very small doses at a time. This is clearly shown by the paralyses of the extremities, which they often cause: and by the dreadful disease, called "painter's colic." But these terrible effects would be diminished, or prevented, by the use of minute quantities of sulphuric acid [308].

549. *Tests for Lead.*—The soluble salts of lead, in the neutral state, redden litmus paper; and are decomposed at a red heat.

Lead, in solution, gives, with potash, or ammonia, white precipitates, which are basic salts, easily soluble in ammonia, but with difficulty in potash. Ammonia, throws down no precipitate, with acetate of lead, a soluble triacetate being formed. Sulphuretted hydrogen, and hydrosulphuret of ammonia, give, with the compounds of lead, a *black* sulphuret ($Pb S$), which is decomposed by boiling

centrated nitric acid. When the solution contains much neral acid, the sulphuretted hydrogen causes no precite, until water is added. The alkaline carbonates, give white carbonate (CO_3+PbO) [548]. Sulphuric acid, the sulphates, a white sulphate (SO_3+PbO), insoluble water, and in dilute sulphuric acid—particularly in the er. Hydrochloric acid, and the soluble chlorides, a ite chloride ($PbCl$), soluble in a large quantity of water specially if heat is applied, but very difficult of solution nitric, or hydrochloric acid. Chromate of potash, a low chromate (CrO_3+PbO), soluble in caustic potash, not in nitric acid. This chromate is used very extenely as yellow paint. Ferrocyanide of potassium, a white rocyanide.

550. Lead is separated from its salts, in the metallic te, by iron, or zinc. If a piece of the latter is suspended, a thread, in a solution containing one part acetate of d, and twenty-four parts water, the lead will be deposited the zinc, in an arborescent form—constituting what is led, from its appearance, "arbor Saturni."*

551. Lithium;†—*symb.* L; *equiv.* 6·55. Sir H. Davy ained this metal, by means of galvanism, from its oxide. e latter, was discovered, in 1818, by Ardfwedson; and s named by him *lithion*, on account of his having deted it in an earthy mineral: but it has since been termed thia." It is procured, from *spodumene*, which is found, ong other places, at Killiney, in the county Dublin; and double silicate of lithia and alumina. The mineral is be carefully pulverized: then, mixed with fluor spar,

* "The tree of Saturn." *Lat.*—The ancients gave the follownames, and symbols, to those metals with which they were far—

Metals.	Names.	Symbols
Gold, . .	The Sun, . .	☉
Silver, . .	The Moon, . .	☾
Mercury, . .	Mercury, . .	☿
Copper, . .	Venus, . .	♀
Iron, . .	Mars, . . .	♂
Tin, . .	Jupiter, . .	♃
Lead, . .	Saturn, . .	♄

† *Lithos*, a stone. *Gr.*

and digested with oil of vitriol. The silica present, forming with the hydrofluoric acid fluoride of silicon [416], and water passes off; the lime, alumina, and lithia, unite with the sulphuric acid. When the other sulphates are dissolved by a small quantity of water, the insoluble sulphate of lime is left behind: and [434] the alumina is precipitated from the filtered solution, by ammonia. The clear liquor is then evaporated: and, what is left being ignited—to decompose the sulphate of ammonia, the residue, which is sulphate of lithia, having been dissolved, is decomposed by nitrate of barytes:—sulphate of barytes is thrown down, and nitrate of lithia is left in solution. When this is evaporated, and decomposed by heat, the residue is lithia. Metallic lithium is procured from this, by galvanic action.

552. Lithium is white, like sodium. It is immediately oxidized by the atmosphere—lithia being produced.

553. It forms, with oxygen, an oxide (LO; 14·55)—"lithia," which is an alkali; and possesses stronger neutralizing powers, than potash, or soda. With chlorine, chloride (LC*l*; 42·02). With fluorine, fluoride (LF; 25·41), &c.

554. *Tests for Lithium.*—When the salts of lithia are heated on platinum wire, by means of the blow-pipe, like strontia, they tinge the flame, red:—if, however, soda is present, it produces its own yellow colour. When lithia is fused on platinum foil, it leaves a yellow trace, round the spot where it was placed. This arises from oxidation of the platinum—which recovers its metallic appearance, on being washed, and heated. It is distinguished from baryta, strontia, and lime, by forming soluble salts with the sulphuric, and oxalic acids; and from magnesia, by its carbonate, which is sparingly soluble in water, forming a solution that has an alkaline reaction.

555. MAGNESIUM:*—*symb.* Mg; *equiv.* 12·62. It was obtained, in small quantities, by Davy, in 1807; but, it is procured, with great facility by the following process—employed by Bussey, in 1829. Small pieces of anhydrous chloride of magnesium are placed upon bits of potassium,

* From the earth magnesia, the name of which, according to Fourcroi, is derived from the word "magnet" on account of some *properties it* was supposed to possess.

in a hard glass tube hermetically sealed at one end. After the chloride has been heated, almost to its point of fusion, a lamp is applied to the potassium :—the latter, rising in vapour, will pass through the chloride, and vivid incandescence will be produced. When the action has terminated, and the whole is quite cool, the resulting chloride of potassium is washed away from the magnesium, with water. $MgCl+K=KCl+Mg$.

556. Magnesium is white, like silver. It is malleable. It melts, at a red heat. It is not oxidized in dry air, nor in boiling water: but it slowly combines with oxygen, in damp air. Heated to redness in atmospheric air, or oxygen, it burns brilliantly, forming magnesia. It takes fire, spontaneously, in chlorine; and dissolves, with facility, in dilute acids.

557. Magnesium forms, with oxygen, an oxide (MgO; 20·62)—"magnesia" an alkaline earth, which is found abundantly, as a carbonate, united with carbonate of lime, in magnesian limestone $[(CO_2+CaO)+(CO_2+MgO)]$. Unlike lime, it does not emit heat, when combining with water. Magnesium forms, with chlorine, chloride ($MgCl$; 48·09). With iodine, iodide (MgI; 139·47). With bromine, bromide ($MgBr$; 92·59). With fluorine, fluoride (MgF; 31·48), &c.

558. *Tests for Magnesium.*—Magnesian salts, in solution, are recognised by forming, with ammonia, a bulky white hydrate ($MgO+HO$). The latter, is not produced, in acid solutions: nor if ammoniacal salts are present—since magnesia forms, with ammonia, soluble double salts. Caustic potash causes a similar precipitate—which disappears, on adding sal-ammoniac, but is reproduced by boiling with excess of potash. Carbonate of potash throws down, in neutral solutions, when ammoniacal salts are not present, a bulky white precipitate $[3(CO_2+MgO+HO)+(MgO+HO)]$, some of which is held dissolved as bicarbonate, until the carbonic acid, which rendered it soluble, is expelled by boiling. Phosphate of soda—if ammonia is added—precipitates a crystalline basic phosphate of magnesia and ammonia $[PO_5+(2MgO+NH_4O)+12Aq]$ which is insoluble in ammoniacal salts, but dissolves in free acids. If the solution contains but a small quantity of the

magnesian salt, the crystalline precipitate forms only on the sides of the vessel—and but slowly there, unless it is rubbed with a glass rod. Before adding the phosphate of soda, it is proper to precipitate barytes, strontia, lime, and the other alkaline earths, by heating with sulphate of potash, and oxalate of ammonia. The sulphate of magnesia, unlike that of lime, &c., is very soluble: and oxalate of ammonia forms no precipitate with magnesian salts, when those of ammonia are present.

If magnesia, or one of its compounds, is moistened with a solution of protonitrate of cobalt, and then strongly heated on charcoal, by the blow-pipe, a slight flesh tint is produced; and it becomes somewhat stronger, on cooling.

559. MANGANESE:*—*symb.* Mn; *equiv.* 27·56. In the form of black oxide, it was discovered by Gahn, in 1774: and was shown to contain a peculiar metal, by Scheele, soon after. It was first called "magnesium:" but afterwards "manganesium," from manganese, the name by which its peroxide was long known. It is very generally, but not very abundantly, diffused through the animal, vegetable, and mineral kingdoms: and may be obtained, in the metallic state, by heating to full redness, in a platinum crucible a mixture of chloride of manganese, carbonate of soda, and sal-ammoniac. Chloride of sodium, and carbonate of manganese, are first formed. $MnCl+(CO_2+NaO)=NaCl+(CO_2+MnO)$. The carbonate is then decomposed, the carbonic acid being driven off; and the oxide of manganese is prevented from combining with any more oxygen, by the sal-ammoniac—which gives hydrogen with facility. The resulting oxide, having been mixed with an equal weight of lampblack, and made into a dough with oil, is to be placed in a crucible coated with clay and charcoal powder; and when it has been subjected, for two hours, to the highest heat of a smith's forge, a button of metallic manganese will be obtained.

560. It is a grayish, white, granular metal. Its specific gravity is 8·013. It is brittle, and very refractory—requiring the most intense heat of a smith's forge for fusion. It soon oxidizes in the air, becoming a black powder. It

* From "magnesia," its black oxide having been called "black *magnesia*."

decomposes water slowly, at ordinary temperatures: but quickly, at a red heat. It dissolves rapidly, in dilute sulphuric acid.

561. Manganese forms with oxygen, protoxide (MnO; 35·56); sesquioxide (Mn_2O_3; 79·12); peroxide (MnO_2; 43·56)—the black oxide [156], called, also, "glass maker's soap," from its whitening glass [392]. It is very important in the arts, &c. When found native, it is almost always contaminated with other substances—generally, with oxide of iron. Manganese forms, also, red oxide (Mn_3O_4; 114·68, believed, by some, to consist of one atom of peroxide, and two of protoxide); *varvicite* (Mn_4O_7; 166·24, supposed to consist of two atoms of peroxide, and one of sesquioxide), so called, because found as a natural production, thus named, in Warwickshire; manganic acid (MnO_3; 51·56), which cannot be obtained, except in combination—since it resolves itself, spontaneously, into peroxide, and oxygen: and permanganic acid (Mn_2O_7; 111·12). With chlorine, protochloride ($MnCl$; 63·03); perchloride (Mn_2Cl_7; 303·41). With sulphur, sulphuret (MnS; 43·56). With fluorine, perfluoride (Mn_2F_7; 187·14), &c.

562. *Tests for Manganese.*—The protosalts of manganese are colourless, or of a pale red colour. The persalts, produce red, or green solutions—which are changed, by sulphurous acid, or sulphuretted hydrogen, to solutions of salts of the protoxide. Both the protoxide, and its hydrate, become brown by exposure to the air—being altered to peroxide.

563. The protosalts, in solution, give, with potash, or ammonia, a whitish hydrated protoxide ($MnO+HO$), which, by absorbing oxygen from the air, becomes brownish, and finally, deep blackish brown—being changed into hydrated peroxide. The precipitate thrown down by potash is diminished, and that, by ammonia, is prevented, by sal-ammoniac—which dissolves the protoxide, forming double salts of manganese and ammonia, that, by exposure to the air, become turbid, and deposit a dark brown hydrated sesquioxide (Mn_2O_3+HO). They give, with the alkaline carbonates, a white carbonate: and with phosphate of soda, a white phosphate. Acid solutions give, with sulphuretted hydrogen, and those that are alkaline, with hydrosulphuret of ammonia, a bright flesh red sul-

phuret (MnS), which is soluble in hydrochloric, or nitric acid, and turns brown, by exposure to the air. The protosalts give, with ferrocyanide of potassium, a ferrocyanide, which, being at first white, becomes pale red, and is soluble in free acids: and, with ferridcyanide of potassium, a brown ferridcyanide.

564. Compounds of manganese, fused with carbonate of soda, in the *outer* flame of the blow-pipe, become green, while hot; but blue-green, and turbid, when cool—manganate of soda (MnO_3+NaO) being produced. The effect is rendered more perceptible, by the addition of a small quantity of nitre. Compounds of manganese, fused with borax, in the *outer* flame of the blow-pipe, form a violet red, or, if there is much manganese—a black button; but the colour is destroyed by the *inner* flame. The same effects are produced, if phosphate of soda and ammonia is employed, instead of borax: except that a black button is never obtained, and the inner flame decolourizes with greater rapidity.

565. MERCURY:—*symb.* Hg;* *equiv.* 100·07. It was known to the ancients: and received its name from the Persians, who supposed its properties next to those of gold—and, therefore, called it after the planet nearest to the sun [550, note]. It is found in the metallic state—sometimes in combination with gold, and silver: but it is most usually obtained, from "cinnabar," a native sulphuret, by heating with lime, or iron filings. Sulphuret of calcium—or of iron—and oxide of mercury, are the results: and the latter is then decomposed, by the heat, into metallic mercury, which passes off in vapour and is condensed, and oxygen, which escapes.

In another process, the cinnabar is roasted in kilns, to burn off the sulphur:—sulphurous acid is evolved, and metallic mercury distils over, and is condensed.

566. The mercury of commerce is adulterated with tin, lead, and bismuth; but it is purified by distillation, or by being kept in contact with dilute nitric acid—which seizes on the impurities, and does not act on the mercury, until they are dissolved. But the process is stopped, before that takes place.

* From *Hydrargyrum* (liquid silver), its Latin name—*hudor*, *water*, and *arguros*, silver. Gr.

567. Mercury is white, and very brilliant. At 60°, its specific gravity is 13·568. Unlike any other metal, it is liquid, and even evaporates, at ordinary temperatures. Hence when, from breaking a thermometer, or any other cause, it is allowed to get into chinks between the boards of a floor, it vitiates the atmosphere. The fumes of mercury, are poisonous to plants. It solidifies at 39° below zero—contracting very much, at the moment of congelation: and its specific gravity, is then 14·0. It boils at 662°. When pure, it is not tarnished by air, or moisture:—but, in the form of vapour, it is slowly oxidized by the atmosphere, or by oxygen—becoming peroxide. It is oxidized, by boiling sulphuric acid, sulphurous acid [306] being evolved. Nitric acid acts powerfully upon it, nitric oxide being given off in large quantities.

568. Mercury forms with oxygen, suboxide (Hg_2O; 208·14), called "black oxide;" and peroxide (HgO; 108·07), called "red precipitate." With chlorine, subchloride (Hg_2Cl; 235·61), called also "calomel;" and perchloride, ($HgCl$; 135·54), called "corrosive sublimate." With iodine, subiodide (Hg_2I; 325·99); protiodide (HgI; 226·92); and sesquiiodide (Hg_4I_3; 780·79). With bromine, subbromide (Hg_2Br; 280·11): and perbromide ($HgBr$; 180·04). With sulphur, subsulphuret (Hg_2S; 216·14); and persulphuret (HgS; 116·07), known as "factitious cinnabar" and when reduced to powder, as "vermilion."

569. Compounds of Mercury, &c.—Mercury unites with many metals, forming compounds which, if soft at ordinary temperatures, are termed "amalgams." It unites, very easily, with gold, silver, lead, tin, bismuth, and zinc; not easily with copper, arsenic, and antimony; and scarcely at all with platinum, or iron. Looking-glasses, are "silvered" with an amalgam consisting of tin and mercury. Some of the metals with which mercury unites, rise along with it, to a greater or less extent, in distillation [heat 88]. If a mark is made across a brass plate, with a stick dipped in a solution of mercury, the latter will be quickly reduced, and penetrate the brass, so that it may be easily broken in that place.

570. *The Peroxide of mercury*, is nearly black when hot, but red, when cold [heat 3]. If obtained by precipitating corrosive sublimate with caustic potash, it is yellow;

and, though identical in constitution with the red, it has such a difference of properties, as indicates it to be in quite another allotropic state [154]. The yellow is dissolved, at once, by oxalic acid; and is changed, by heat, into the red.

571. *Protonitrate of mercury* (NO_5+Hg_2O), may be formed, by gently heating nine parts nitric acid, specific gravity 1·23, with ten parts mercury; and, when gas is no longer disengaged, boiling the solution along with the undissolved mercury—the water being replaced, according as it is evaporated—until, if common salt is added in excess, protochloride of zinc will produce no further precipitate. The whole is then to be agitated, until it is cold: and the resulting crystals are to be dissolved in twenty parts cold water, slightly acidulated with nitric acid. The solution is to be filtered, and kept in a bottle, the bottom of which is covered with mercury.

572. *Perchloride of mercury* ($HgCl$), may be obtained sufficiently pure, by recrystallizing that of commerce.

573. *Tests for Mercury.*—The soluble salts of the suboxide of mercury redden litmus paper. Potash gives, with their solutions, the black suboxide. Ammonia, gives a black precipitate, which is a basic double salt of mercury and ammonia (for example, with the nitrate, it is $NO_5+NH_3+2Hg_2O$). Phosphate of soda, gives a white precipitate; iodide of potassium, a greenish yellow, soluble in excess; chromate of potash, a red; sulphuretted hydrogen, and hydrosulphuret of ammonia, black subsulphurets—dissolved, and decomposed, by aqua regia, but not by boiling nitric acid. Hydrochloric acid, and the soluble metallic chlorides, give a dazzling white sub-chloride, that dissolves in aqua regia, or chlorine water—becoming perchloride: and is decomposed, by ammonia and potash—black suboxide being separated. Protochloride of tin, gives a gray precipitate, which consists of metallic mercury, and changes into globules, by heating and agitation, but, more readily, by boiling with hydrochloric acid. Ferrocyanide of potassium, gives a white precipitate, which gradually becomes bluish.

574. The persalts, give with potash, a yellow hydrated oxide ($HgO+HO$): this precipitate is reddish brown, with an insufficient quantity of the re-agent. Ammonia, gives *a white* precipitate, which is a compound of amidide of *mercury* ($HgNH_2$), and some of the undecomposed salt.

Thus, with protochloride, the reaction is $2HgCl+2NH_3=(HgNH_2+HgCl)+(HCl+NH_3)$. This salt is produced, also, when the reddish brown precipitate, thrown down from the solution of a salt of the oxide of mercury, by the fixed alkaline carbonates, is acted on by ammoniacal salts. Sulphuretted hydrogen, and hydrosulphuret of ammonia, in small quantity, the solution being agitated, give a white precipitate, consisting of sulphuret of mercury, and undecomposed salt: but, in larger quantities, a yellow, orange, brown, red, or black—the resulting sulphuret being soluble in aqua regia, but not in boiling nitric acid. Phosphate of soda, gives a white precipitate. Iodide of potassium, gives a red precipitate, which is soluble in excess, and crystallizes, from a hot solution, in beautiful crimson spangles. Protochloride of tin, produces the same effect as with solution of the suboxide [573]. Ferrocyanide of potassium, gives a white precipitate, which gradually becomes bluish. Ferridcyanide of potassium gives, with solutions of the nitrate, and sulphate, but not with that of the chloride, a yellow precipitate.

575. Mercury may be detected, in solution, by placing a drop of the suspected liquor on clean gold, and touching the moistened surface with iron wire, or the blade of a penknife:—the point of contact will become white, on account of an amalgam of gold being formed. The solution of any mercurial salt, rubbed on clean copper, gives a brilliant surface of metallic mercury. If a small quantity of iodide of potassium, is added to a drop of a solution containing an exceedingly minute quantity of a salt of mercury, and the mixture is then placed on a piece of clean bright copper, a silvery stain is immediately produced by the mercury which separates in the metallic state. This does not occur with any other metal, and is supposed to be due to an easily decomposable soluble salt of mercury being formed, by the iodide of potassium. The oxides of mercury are reduced, in close vessels, by mere heat.

576. Many animal, and vegetable substances, slowly convert perchloride of mercury, into subchloride:—albumen produces this effect rapidly, and forms a harmless compound with the resulting calomel. Hence, white of eggs is an antidote for corrosive sublimate.

CHAPTER V.

The Metals continued—Molybdenum, 577.—Nickel, 582.
pounds of Nickel, &c., 585.—Niobium, 588.—Osmium
Palladium, 594.—Pelopium, 598.—Platinum, 599.—Co
of Platinum, &c., 601.—Precautions to be observed
Platinum, 604.—Potassium, 607.—Compounds of P
&c., 610.—Rhodium, 625.—Ruthenium, 631.—Silve
Compounds of Silver, &c., 640.—Sodium, 643.—Com
Sodium, &c., 646.—Strontium, 653.—Tellurium, 656.—
659.—Thorium, 660.—Tin, 663.—Compounds of Tin,
—Titanium, 670.—Tungsten, 674.—Uranium, 679.—V
683.—Yttrium, 688.—Zinc, 692.—Compounds of Zinc
—Zirconium, 697.—Comportment of the Metals, with
700.

577. THE METALS CONTINUED—MOLYBDE
symb. Mo.; *equiv.* 47·96. It was discovered by
in 1782; and is obtained, from its bisulphuret
very much resembles "black lead," in appearance
digesting it, in a state of minute division, with aq
and heating the residue, to expel the sulphuric ac
lybdic acid, a heavy white powder is left behi
when this is heated, as strongly as possible, with
in a smith's forge, metallic molybdenum is the res

578. Molybdenum is a brittle, white metal. S
fic gravity, is 8·6. It has never been more than se
Heated in the atmosphere, it becomes molybdic a
is acted upon only by concentrated nitric, and s
acids; and by aqua regia.

579. Molybdenum forms, with oxygen, molybde
(MoO; 55·96); molybdic oxide (MoO_2; 63·96); m
acid (MoO_3; 71·96); and molybdate of moly
($Mo_3O_8 = MoO_2 + 2MoO_3$: 207·88), a blue powd
times used in calico printing. With sulphur, bis

* *Molubdos*, lead, *Gr.*; because found in a mineral,
posed to be "black lead."

MoS_2; 79·96): tersulphuret (MoS_4; 95·96); and persulphuret (MoS_4; 111·96), &c.

580. *Tests for Molybdenum.*—Molybdous oxide, in solution, gives with potash and ammonia, a brownish black precipitate: and with the carbonates of potash, and ammonia, a similar precipitate, slightly soluble in the former—but more so, in the latter. With hydrosulphuret of ammonia, a yellowish brown precipitate, soluble in excess.

Molybdic oxide is completely thrown down by sal-ammoniac, as a reddish brown hydrate, which is similar in appearance to hydrated sesquioxide of iron, and which is dissolved by carbonate of ammonia, but reprecipitated by boiling.

The oxides of molybdenum give to microcosmic salt a green, and to borax, a brownish red colour, in the inner flame of the blow-pipe.

581. Molybdic acid, in an acid solution, gives with sulphuretted hydrogen, in excess—after a while—a brown precipitate, which subsides slowly, leaving the supernatant liquor blue, or green. Nitrate of silver gives, with solutions of molybdic acid, a white precipitate, which is soluble in a large quantity of water, in ammonia, and in nitric acid. Chloride of barium gives a white precipitate, soluble in nitric acid. Metallic zinc, or tin, when free hydrochloric acid is present, colours solutions containing this acid, blue, then green, and finally black.

582. NICKEL:*—*symb.* *Ni*; *equiv.* 29·53. It was discovered by Cronstedt, in 1751: and is best obtained from *speiss*, and artificial arseniuret produced in the manufacture of "smalt" [483], by reducing it to a fine powder, and then digesting it with sulphuric acid, which contains a fourth part nitric acid, and is diluted with water. This forms sulphate of nickel, and arsenious acid:—the latter is separated by concentrating, then leaving the solution at rest for some hours, and afterwards filtering. A solution of carbonate of potash is next added to the clear liquor, until the green precipitate thrown down ceases to be redissolved;—after which, if left quiet, the double sulphate

* So called, because found in ores, termed by the German miners, "kupfer nickel," *false copper*; being mistaken by them for *that metal*.

of potash and nickel will crystallize, of itself. The
tals being dissolved, any copper contained in them,
parated by sulphuretted hydrogen—as also any arsen
the form of sesquisulphuret. The free sulphuric a
then driven off, by heat: the oxides of nickel, cobal
iron are precipitated, by ammonia: and the two f
being dissolved, by excess, are removed. The cobal
ing been separated from the nickel, by the metho
have already described [478], oxide of nickel, or o
is again formed. Metallic nickel, is obtained fro
oxide, by acting upon it when at a high temperature
carbon, or hydrogen; and, from the oxalate, by heat
in close vessels. $C_2O_3+NiO=2CO_2+Ni$. The ni
in the form of a light sponge.

583. Nickel is white, like silver. Its specific grav
after fusion, 8·5:—but it is rendered more dense, by
mering. It is malleable, both when hot and cold.
rather more fusible than iron, but less magnetic. Its
netism, which is permanent like that of steel, is alto
destroyed by the presence of very little arsenic, or
temperature of 630°. It is almost as little liable t
nish, in damp air, as platinum, gold, or silver: bu
partially, though not rapidly, oxidized at a red heat.
acted upon, with difficulty, by hydrochloric, or sul
acid: but is dissolved, with facility, by nitric acid.

584. Nickel forms with oxygen, protoxide (NiO; 3
and peroxide (Ni_2O_3; 83·06). With chlorine, ch
($NiCl$; 65). With sulphur, disulphuret (Ni_2S; 7
protosulphuret (NiS; 45·53). With phosphorus, sul
phuret (Ni_2P_2; 151·23), &c.

585. Compounds of Nickel, &c.—Nickel is u
the arts, to produce, with other metals, some very b
ful compounds—1 part nickel, and 5 of brass, for
Chinese "packfong;" and also an inferior kind of G
silver. Increasing the nickel up to 6 parts, gives
nations of progressively increasing beauty, but of g
cost, also. A combination, containing 6 parts nick
scarcely be distinguished from silver. When there is
nickel, arsenic, even in minute quantities—and it i
difficult to banish it altogether—would render the
hard, and liable to flaws.

586. *Tests for Nickel.*—The protoxide is the only oxide, that forms salts;—it is precipitated, by potash, as a light green hydrate ($NiO+HO$), which is dissolved by carbonate of ammonia, the solution being green. The same precipitate is thrown down by ammonia, and is redissolved by excess, the solution being blue:—ammonia gives no precipitate, in the presence of ammoniacal salts, or of free acid. The alkaline carbonates, throw down a green precipitate—which is redissolved by the carbonate of ammonia. Sulphuretted hydrogen, throws down, from alkaline, and hydrosulphuret of ammonia, from neutral solutions, a black sulphuret (NiS) readily soluble in aqua regia:—the fluid from which this precipitate separates, is generally brownish, a small quantity being redissolved, on account of the presence of free ammonia, or pentasulphuret of ammonia. Cyanide of potassium, throws down a greenish yellow cyanide ($NiCy$), which dissolves in excess, a double cyanide of nickel and potassium ($NiCy+KCy$) being produced:—sulphuric, or hydrochloric acid, reprecipitates the cyanide of nickel. Ferrocyanide of potassium, throws down a yellowish green: and ferridcyanide of potassium, a yellowish brown precipitate.

587. Borax, and microcosmic salt give, with compounds of nickel, in the outer flame of the blow-pipe, dark yellow buttons, which have a tinge of red brown, but become almost colourless, by cooling:—the addition of nitre, or carbonate of potash, changes the colour to blue, or dark purple. The button formed by microcosmic salt is not altered by the inner flame, but that obtained with borax, is rendered by it gray, and turbid.

588. Niobium:*—*symb.* Nb. The existence of this metal, was pointed out, by Rose. It is obtained from the American, or Bavarian tantalite, as niobic acid.

589. *Tests for Niobium.*—Ferrocyanide, and sulphocyanide, of potassium give, with solutions containing niobium, a dark yellow precipitate. Solutions containing niobic acid, become of an orange red, when tincture of galls is added: but those containing tantalic acid, of a

* This metal and *pelopium*, obtained their names, on account of belonging to the *tantalite* family—called after Tantalus, Niobe, and Pelops, in heathen mythology.

clear yellow colour. A slip of zinc, introduced into solutions which contain niobic acid—and also free hydrochloric acid—produces, first a blue, then a brown tint, and lastly, a brown precipitate: but with salts of tantalic acid, in the same circumstances, white tantalate of zinc is gradually thrown down. Tantalic acid is known also by the precipitates it affords [487] with ferrocyanide, and sulphocyanide of potassium. Niobate is distinguished from tantalate of soda, by being soluble.

590. Osmium:*—*symb.* Os.; *equiv.* 99·72. It was discovered by Tennant, in 1803. Particles of it, combined with iridium, are found, mechanically mixed with the ore containing platinum, rhodium, and palladium: and it is obtained, from the pulverulent residue of platinum ore—after the platinum, rhodium, and palladium have been removed, by digestion with aqua regia—by grinding it to a fine powder, and heating it to redness, along with the third of its weight of nitre, in a silver crucible, until it becomes pasty. The peculiar odour of the oxide of osmium will then be perceived: and the soluble parts, which contain it in combination with potash, being dissolved with as little water as possible, the solution is acidulated, and poured into a retort, along with its own weight of water: and then distilled rapidly, as long as the odour is perceptible. The osmic acid, which will be collected on the sides of the receiver as a white crust, will, on melting, run down in drops, and form, in the watery solution, a liquid flattened globule, which crystallizes, as the receiver cools. Metallic osmium may be precipitated from the solution of this acid, by any of the metals—except gold, or silver: or, by agitating with mercury, dissolving the resulting protoxide of that metal with hydrochloric acid, and driving off both mercury and calomel, by raising the temperature.

591. Osmium, thus obtained, is a black powder; but with heat, and compression, it becomes like platinum—though less brilliant. When most dense, its specific gravity is 10·0. It is easily pulverized. While in the form of powder, it burns in the atmosphere, if it is heated to redness: and it may be oxidized by nitric acid:—but, after it has been ignited, it loses these characters.

* *Osmē*, an odour, *Gr.*, from the irritating nature of its acid.

592. Osmium forms, with oxygen, protoxide (OsO; 107·72); sesquioxide (Os_2O_3; 223·44); deutoxide (OsO_2; 115·72); teroxide (OsO_3; 123·72); and osmic acid (OsO_4; 131·16), which is volatile, and though it has not an acid reaction, combines with bases. With chlorine, protochloride ($OsCl$; 135·19); sesquichloride (Os_2Cl_3; 305·85); bichloride ($OsCl_2$; 170·66): and terchloride ($OsCl_3$; 206·13). With sulphur, protosulphuret (OsS; 115·72); sesquisulphuret (Os_2S_3; 247·44); bisulphuret (OsS; 131·72); and tersulphuret (OsS_2; 147·72), &c.

593. *Tests for Osmium.*—Salts of osmium, are recognised, by heating them on platinum foil, with carbonate of soda:—osmic acid will be evolved, and easily known by its action on the eyes and lungs. They afford, with sulphuretted hydrogen, and hydrosulphuret of ammonia, a brown black precipitate. Solutions containing osmic acid combined with alkalies, become, when tincture of gall is added, of a colour which being at first purple, changes to deep blue: and is made, by sulphurous acid, to pass through the shades of yellow, orange, brown, green, and blue—from sulphates of the different oxides being produced, the last tint being caused by a compound of oxide and sesquioxide. Osmium is reduced to the metallic state, not only by many metals, but also by several organic compounds.

594. PALLADIUM:*—*symb.* Pd; *equiv.* 53. It was discovered by Wollaston, in 1803: and is found in ores of platinum. When the latter has been separated from its solution in aqua regia, by means of sal-ammoniac, and filtration, the residual liquor is neutralized with soda: after which, the palladium is thrown down by cyanide of mercury. The resulting cyanide, being decomposed by ignition, palladium is obtained in the metallic state.

595. It is like platinum, but harder. Its specific gravity is 11·5. It is malleable, and ductile. It is more fusible than platinum. Heated below ignition, its surface becomes covered with a blue, or green, coating of suboxide: but, when the temperature is raised, the metal is reduced, oxygen being driven off. Palladium burns with the emission of sparks, under the oxy-hydrogen blow-pipe. Like

* From the planet Pallas.

iron, it welds. It is insoluble in sulphuric, or hydrochloric acid:—but is soluble in nitric acid, and aqua regia.

596. Palladium forms, with oxygen, suboxide (Pd_2O; 114); oxide (PdO; 61); and deutoxide (PdO_2; 69). With chlorine, protochloride ($PdCl$; 88·47): and bichloride ($PdCl_2$; 123·94). With sulphur, sulphuret (PdS; 69), &c.

597. *Tests for Palladium.*—The oxides of palladium produce beautiful red coloured salts, from which the metal itself is precipitated, in the metallic state, by sulphate of the protoxide of iron, by sulphurous acid, by a formiate, and by nearly all the metals but gold, silver, and platinum.

Palladium gives, with potash, a yellowish brown basic salt, soluble in excess. With iodide of potassium, a black precipitate. With sulphuretted hydrogen, or hydro-sulphuret of ammonia, a black precipitate, soluble in the hydrosulphuret. With cyanide of mercury, or of potassium, a yellowish white cyanide, soluble in a large quantity of hydrochloric acid. Palladium may, by means of sulphuretted hydrogen, be separated, from all the metals not precipitated by that re-agent. The resulting sulphuret is changed, by heat, into basic sulphuret, soluble in hydrochloric acid. Chloride of palladium gives, with ammonia, a flesh red precipitate ($PdCl+NH_3$), soluble in excess.

598. PELOPIUM:*—*symb.* Pe. It was shown, by Rose, to exist in combination with tantalum and niobium; and is obtained, by passing chlorine over a mixture of niobic acid and powdered charcoal, raised to a red heat:—chlorides of niobium, and pelopium are produced; and the latter sublimes into a distant part of the tube. The chloride of pelopium being then saturated with ammoniacal gas, and ignited, water, hydrochloric acid, and metallic pelopium are the results. Very little is known, regarding this metal.

599. PLATINUM.†—*symb.* Pl; *equiv.* 98·84. It was discovered by Wood, Assay-master of Jamaica, in 1741:

* See note page 203.

† *Platina*, little silver, from *plata*, silver, *Sp.*—on account of its resemblance to that metal. Its name, according to others, is derived from that of the river Plata, in South America, near which it is found.

and occurs only in the metallic state, combined with other metals. It is obtained pure in commerce.

Platinum is not so brilliant as silver. Its specific gravity is 21·5. It is, therefore, the heaviest of all metals, and, indeed, of all known substances. It is malleable, ductile, and, like iron, capable of being welded. It melts under the oxy-hydrogen blow-pipe. It is not affected by the atmosphere: but it is slightly oxidized when nitre, or potash, are melted upon it, or when some metals are reduced in contact with it. It is dissolved only by aqua regia, and hydrofluoric acid.

600. Platinum forms, with oxygen, protoxide (PlO; 106·84); and deutoxide (PlO_2; 114·84). With chlorine, protochloride ($PlCl$; 134·31); and bichloride ($PlCl_2$; 169·78). With iodine, protiodide (PlI; 225·69); and biniodide (PlI_2; 352·54). With sulphur, protosulphuret (PlS; 114·84); and bisulphuret (PlS_2; 130·84), &c.

601. Compounds of Platinum, &c.—*Bichloride of platinum* ($PlCl_2$) may be obtained, by dissolving the metal in nitro-muriatic acid, evaporating the solution to dryness in a water bath, and redissolving in water.

Spongy platinum, is very conveniently obtained, by dropping a solution of platinum on blotting paper, fixing the latter to a wire, and igniting it in the flame of a spirit lamp.

602. *Tests for Platinum.*—Platinum, in a solution which is not too dilute, and, in the presence of free hydrochloric acid, gives, with potash, ammonia, chloride of potassium, or sal-ammoniac, a yellow crystalline precipitate, the potassio-chloride ($KCl+PlCl_2$), or ammonio-chloride ($NH_4Cl+PlCl_2$) of platinum, which is soluble in excess, the temperature being raised, and produces [193] spongy platinum, when heated to redness. If the latter is obtained from the ammonio-chloride, hydrochloric acid is formed by the chlorine combining with hydrogen, derived from some of the ammonia which is decomposed. Sulphuretted hydrogen, and hydrosulphuret of ammonia, throw down, in acid, and in neutral solutions, a blackish brown bisulphuret, which dissolves—slowly, at ordinary temperatures, but immediately, if heated—in aqua regia, or in hydrosulphuret of ammonia containing an excess of sulphur [253]. *Protochloride of* tin, changes peroxide of platinum,

in solution, to protoxide—which may be known by iodide of potassium, in excess, imparting to the liquor a red colour, when a drop of nitric acid, or of chlorine water, is added. It gives, with chloride of platinum, a chocolate coloured precipitate, or, when the quantity of platinum is small, a deep reddish brown solution, the bichloride of platinum being altered to protochloride. Iodide of potassium gives a corresponding iodide, in the form of a black precipitate, soluble in excess—the solution being a rich crimson colour.

Platinum is thrown down from its solutions, in the metallic state, as a black powder termed "platinum black," by immersing in them a slip of zinc, and boiling the precipitate, for a little while in hydrochloric acid. This substance, like spongy platinum, causes gases to unite. It is useful, also, in organic chemistry.

603. Platinum, when perfectly clean, has the property of making gases [193] combine. It is rendered sufficiently free from foreign substances, by fusing upon it some caustic potash, washing off the alkali with distilled water, then dipping the platinum in hot oil of vitriol, and again washing it. Touching the clean surface, exposing it to the atmosphere for a few days, &c., diminish, or altogether destroy its power:—the same effect is produced by small quantities of olefiant gas, sulphuretted hydrogen, carbonic oxide, and of other gases.

604. PRECAUTIONS TO BE OBSERVED, IN USING PLATINUM.—Since platinum is highly important to the chemist, and is, at the same time, a very expensive substance, the following suggestions regarding the mode of using it, will not be inappropriate—

It should not be employed in fusing the caustic alkalies, nor in calcining lime, barytes, or strontites: nor in heating alkaline nitrates—since the affinity of the alkali, for oxide of platinum, causes a considerable oxidation on its surface. The alkaline sulphurets, or other sulphurets, mixed with charcoal, are, in similar circumstances, still more injurious. A metal in the state of *regulus** injures platinum, since

* From *rex*, a king. *Lat.* The metallic matter, separated from other bodies by fusion, was so named by the alchymists, who expected it to contain gold—called by them [358, note] the king of *metals*.

the latter combines with it at the temperature of fusion. It is completely perforated by a single drop of bismuth, tin, or lead. Gold, silver, or copper, below the temperatures of fusion, do not affect platinum. The oxides of metals, which lose their oxygen at a white heat, cannot be raised to that temperature, in platinum; for the latter would combine with the reduced metal. The oxides of bismuth, copper, lead, and nickel, at a high temperature, are very injurious to platinum; but, at a moderate, they do not act upon it. The student should bear in mind, that clay-slate generally contains small quantities of copper. Phosphorus, and phosphoric acid, mingled with combustible matters, would form phosphuret of platinum. Silicon, and carbon, combine with platinum:—hence, the latter must not be brought in contact with wood, at a high temperature. The soot, from the smoke of a lamp, diminishes the weight of platinum; and it is found, when examined, to contain that metal—which is sometimes even perforated by it. This injurious effect is increased by the presence of copper—which also may be detected in the soot: but it is not so bad as might be anticipated from the fact that spongy platinum, when mixed with powdered charcoal, melts in a platinum crucible. Since chlorine acts on platinum, aqua regia must not be put in contact with it, nor must any manganiferous substances [328] be dissolved in it, with hydrochloric acid. Hence, when, during the analysis of a mineral, the mass obtained by fusion with an alkaline carbonate, is green, or black, hydrochloric acid must be added to it in a *glass* vessel—in which, also, the evaporation must be continued, until the odour of chlorine is no longer perceptible. Polished platinum, is less easily affected than that which is rough:—the latter, even after the foreign substance has been removed, is injured by being merely heated to redness. When, therefore, the surface has, from any cause, lost its smoothness, it must, before it is used, be flattened, and polished, with a hammer. The stains left on platinum, by certain substances, may, with care, be taken away, without doing any harm, by washing it with sand, the particles of which are round. When the stains are of a more permanent character, the surface may be cleaned by a little vitrified borax.

605. Gold may be used for repairing holes, or cracks, in platinum; but a high heat would melt that metal, which would then combine with the platinum. It is better, therefore, to put upon the crack, &c., several layers of a varnish, formed of oil of turpentine and platinum—obtained by mixing the ammonio-chloride [602] with twice its weight of common salt, heating the mixture to redness, and then washing away the common salt from the reduced metal, with water. When the different layers of the varnish are well dried, the flame of a spirit lamp, urged with oxygen, is to be thrown upon it:—and to avoid a loss of heat by radiation, during the process, the interior of the vessel to be repaired should be filled with a piece of porous charcoal of the proper shape; and the outside should be covered with another piece—an aperture, to admit the flame, being left opposite to the part which is being repaired, and which is to be alternately hammered, and heated, until all trace of the injury has disappeared.

606. To preserve a platinum crucible, from the impurities generally contained in ordinary fuel, it is well, during an operation which requires a high temperature, to keep it within a small Hessian crucible.

607. Potassium:*—*symb.* K;† *equiv.* 39·12. It was discovered in 1807, by Davy, who obtained it from caustic potash, by means of the galvanic battery. It may be procured, by igniting "cream of tartar" ($2\overline{T}+KO$) in a covered crucible. The tartaric acid is decomposed, and the residue, which consists of carbonate of potash, and carbon in a state of minute division, is to be well mixed, while hot, with coarsely powdered charcoal—that it may be sufficiently porous, to allow the escape of gases which will be generated—and placed in an iron mercury bottle [82]. The latter is then to be laid on its side, in a wind furnace—a communication having been formed, by an iron tube, between it, and a vessel partly filled with rectified naptha,

* So called, because it is the base of *potash*—which derives its name from the "pots," in which it was originally obtained from the ashes of vegetables.

† From *kali*, the name of a plant, whence the Arabs obtained *alkalies*. The particle "al," was intended, by them, to signify *that the alkali* is superior, in its properties, to the plant itself.

and surrounded with ice. The gases pass off, under partitions fixed in the receiver: and the whole is so arranged, that the tube may, from time to time, be cleaned with an iron wire, to free it from a compound of potassium and carbonic oxide, which is formed within it during the process—and which, indeed, causes a waste of half the potassium. Atmospheric air must not be allowed to enter the apparatus. When the bottle is white hot, the potassium distils over. Potash, and the carbonic acid in combination with it, are decomposed; and the atom of oxygen, liberated from each, unites with carbon, carbonic oxide being formed. $(CO_2+KO)+2C=K+3CO$. The potassium, obtained in this way, may be purified from the compound of carbonic oxide and potassium, and the carbon associated with it, by redistillation from cast iron retorts, out of which the atmospheric air has been expelled with vapour of naptha.

608. Potassium, is of a bluish white colour. Its specific gravity, is 0·865. It is, therefore, lighter than water, and by consequence floats upon that fluid. At ordinary temperatures, it is soft, like wax; at 32°, it is brittle, and crystallizes in cubes; at 70°, it is pasty; at 150°, a liquid; and it boils at a dull red heat, the vapour being green. In the air, it becomes immediately tarnished, by a coating of oxide:—and must, therefore, to exclude the oxygen, be preserved in vacuo, or in vessels of naptha. Heated in the atmosphere, it burns with a bluish flame. It decomposes water, or even ice, with great rapidity, potassiuretted hydrogen—which takes fire spontaneously—being evolved. During the process, the potassium moves about rapidly on the surface of the water: and the resulting globule of caustic potash, when it has cooled a little, suddenly combines with and is dissolved in the water—a loud report being produced. On account of its great affinity for oxygen, potassium, as we have seen more than once, enables the chemist to deoxidize metals, otherwise very difficult to be reduced. At high temperatures, it has a less affinity for oxygen than iron, or carbon, which is not the case, when the heat is lower.

609. Potassium forms, with oxygen, protoxide (KO; 47·12), *ordinarily* called "caustic potash," "potash," or

"potassa," and by the Germans "kali:" and peroxide (KO_3; 63·12). With chlorine, chloride (KCl; 74·59). With iodine, iodide (KI; 165·97). With bromine, bromide (KBr; 119·09). With fluorine, fluoride (KF; 57·98). With sulphur, protosulphuret (KS; 55·12); bisulphuret (KS_2; 71·12); tersulphuret (KS_3; 87·12); tetrasulphuret (KS_4; 103·12); and pentasulphuret (KS_5; 119·12). With cyanogen, cyanide, &c.

610. Compounds of Potassium, &c.—*Potash.* The aqueous solution of potash or the "aqua potassæ"* of pharmacy, may be obtained, by decomposing carbonate of potash with an equal weight of slacked lime. The potash should be previously dissolved in ten times its weight of hot water; since a solution of carbonate of potash, which does not contain at least six times its weight of water, is not decomposed by lime; but, on the contrary, a strong solution of caustic potash decomposes carbonate of lime—carbonate of potash being formed, and caustic lime liberated. When the decomposition of the carbonate of potash is effected, at ordinary temperatures, the resulting carbonate of lime is very light, occupies a large space, and is not so easily removed. The solution, therefore, containing the lime is to be boiled strongly in a clean iron vessel, for ten minutes; and, after it has rested for a while, the supernatant solution of caustic potash may be decanted off from the carbonate of lime, which has subsided. If the potash is rendered impure by the presence of lime, air from the lungs, blown through it, will precipitate carbonate of lime: if it contains undecomposed carbonate of potash, the addition of an acid will produce effervescence.

611. A solution of potash is strongly alkaline, very acrid, and corrosive. It acts energetically on many organic substances: and has, when rubbed between the fingers, a peculiar feel, on account of forming a kind of soap with the cuticle. It has an exceedingly strong affinity for carbonic acid: hence, that gas may, by means of it [263], be removed from others. It absorbs carbonic acid rapidly from the atmosphere, and must, therefore, be kept in well-stopped green [393] glass bottles. It is the basis of soft soaps. It dissolves the oxides of antimony, arsenic, cobalt,

* Water of potash. Lat.

lead, manganese, molybdenum, nickel, tellurium, tin, tungsten, and zinc: also many animal substances.

612. *The protohydrate of potash*, is obtained by evaporating the aqueous solution in a silver, or clean iron vessel, to the consistence of oil: then pouring it out; dissolving it in alcohol, to free it from any oxide of iron, chloride of potassium, carbonate, or sulphate of potash, which it may contain; and again evaporating. To prevent carbonic acid being absorbed from the atmosphere, the process must be carried on rapidly:—the vapour, which rises from the fluid, will prevent the atmospheric air from coming in contact with it. If carbonate of potash is present, it will not melt with the hydrate, and may be removed with a silver skimmer. When the potash is fused perfectly, it is to be poured out on clean iron, &c.: and, being broken in pieces, it must be put into a well-stopped bottle, as soon as possible. Its composition is KO+HO. On account of destroying animal substances, it is used in medicine, as a caustic, under the name of "potassa," or "potassa fusa."* It is very deliquescent:—dissolved in water, and crystallized, its composition becomes KO+5HO.

613. *Carbonate of potash* (CO_2+KO), a salt of great utility in chemical analyses, &c., may be conveniently obtained, by exposing the bitartrate (2T+KO) to a high heat, which decomposes the vegetable acid, carbonate of potash being formed. The latter may be rendered perfectly pure by solution, filtration—to separate the charcoal—and evaporation. The result is a granular mass, formerly called "salt of tartar." When crystallized, its composition is CO_2+KO+2A*q*. It is nearly insoluble in alcohol. Since common cream of tartar almost always contains tartrate of lime, when the carbonate is intended for delicate, or important purposes, it is proper to form the bitartrate, by saturating caustic potash with tartaric acid.

614. *Sulphate of potash* (SO_3+KO), may be obtained by neutralizing carbonate of potash, with sulphuric acid.

615. *Chlorate of potash* (ClO_5+KO), which is important in commerce, on account of its being used extensively in the manufacture of matches, and is very useful to the chemist, in a variety of ways, may be formed by pass-

* Fused potash. *Lat.*

ing a current of chlorine through a strong solution of caustic potash (KO). Chloride of potassium (KCl), and hypochlorite of potash ($ClO+KO$), are the results. $2KO+2Cl=KCl+(ClO+KO)$. When the liquor, in which these are contained, is boiled for some time, the hypochlorite is decomposed, oxygen being given off, and chloride of potassium, along with chlorate of potash, being formed. $9(ClO+KO)=O_{12}+8KCl+(ClO_5+KO)$. The chlorate may be easily separated from the chloride, as it crystallizes sooner, if the liquid is concentrated. It may be formed without the chloride, and, therefore, more economically, by passing chlorine through a pasty mixture containing five and a-half atoms quick-lime, and one of caustic potash, with water at a boiling temperature; chloride of calcium, and chlorate of potash, are the results. If the mixture were at the temperature of the atmosphere, almost no chlorate would be formed. The result must be filtered, evaporated to dryness, redissolved in boiling water, and allowed to cool, when the chlorate of potash will separate. Chlorate of potash exhibits, in a striking manner, the facility with which chloric acid yields its oxygen. When placed on red-hot charcoal, it deflagrates like nitre. It was, for a considerable time, used by the French, as a substitute for nitre, in the manufacture of gunpowder: but the explosive nature of a mixture containing this salt and sulphur [122], caused several lives to be lost. It forms a gunpowder stronger than the ordinary kind: for, when nitre is one of the ingredients, the effect is diminished, by some of the carbonic acid [238] uniting with the potash. Too much caution cannot be observed, in experiments, or processes, in which chlorate of potash is employed. Indeed the greatest care must be taken, whenever an explosion may happen, either by accident, neglect, or inadvertence. Many of the substances we have occasion to mention, should be avoided, by the inexperienced: and we notice some of them, with scarcely any other object than to prevent the accidents, which might occur from their unintentional production.

616. Lucifer matches, are made by dipping the ends of small pieces of wood, &c., in melted sulphur: and then in *a mixture* containing chlorate of potash, along with sul-

phur, and charcoal, with sulphuret of antimony, or with cinnabar (H*g*S), and made into a paste with gum arabic. It is necessary to dip the match, previously, in the sulphur, or the combustion would be too rapid to ignite the wood, &c. Stearine is sometimes used, instead of sulphur, for coating the match; but it does not always inflame. *Noiseless* lucifer matches contain nitre, and phosphorus: the phosphorus has a very great affinity for oxygen [321], the nitre contains a large quantity of it [238], and a very slight cause—friction, for instance—is sufficient to make them combine. According to Böttger, sixteen parts gum arabic, nine parts phosphorus, fourteen parts nitre, and sixteen finely divided peroxide of manganese, form an excellent composition for coating the sulphur. To avoid danger, they must be worked up with water.

A mixture of chlorate of potash and sulphur, was formerly used for the percussion caps of detonating guns; but fulminate of the suboxide of mercury, is now employed for the purpose.

617. *Antimoniate of potash* (SbO_5+KO), may be made, by mixing one part antimony of commerce, with four parts nitre in powder, and throwing the mixture, by little at a time, into a crucible heated to dull redness. When the pasty mass has been kept stirred for about half an hour, it is cooled, washed with water, so as to dissolve out the nitrate and nitrite of potash, and heated to full redness for half an hour in a Hessian crucible, along with somewhat less than half its weight of carbonate of potash. After having cooled, it is digested with twenty parts warm water, and filtered, when cold.

618. *Chromate of potash* ($Cr O_3+KO$), may be obtained by dissolving the bichromate of commerce in water, and adding carbonate of potash, until there is a slight alkaline reaction. Crystals of the neutral chromate of potash, will separate from the resulting yellow liquid, when it is concentrated.

619. *Chloride of potassium* (K*Cl*), may be obtained by neutralizing carbonate of potash [613], with hydrochloric acid.

620. *Iodide of potassium* (KI), may be obtained by adding iodine to a hot solution of caustic potash, until the

latter is neutralized. The result is iodide of potassium, and iodate of potash. $(IO_5+KO):-6KO+6I=5KI+(IO_5+KO)$. On evaporating the solution, containing these compounds, to dryness, and bringing the residue to a gentle red heat, in a platinum crucible, the iodate gives off its oxygen, and becomes iodide of potassium.

621. *Sulphuret of potassium* (S_2K), may be obtained, as a reagent, by fusing carbonate of potash with its own weight of sulphur. The carbonic acid is driven off, and a mixture of sulphate and sulphuret is left behind.

622. *Cyanide of potassium* ($K.C_2N$), may be formed, by fusing at a bright red heat, in a covered iron crucible, eight parts roasted yellow prussiate, with three parts very dry carbonate of potash, until it becomes calm and clear: then pouring the melted mass carefully into a warm dish: and, when cold, breaking it in pieces. It must be kept in a well-stopped bottle, and be dissolved according as it is required.

623. *Tests for Potassium.*—Potassium is known, in neutral, and acid solutions, by giving, with bichloride of platinum, the double chloride [602], distinguished from the analogous ammonio-chloride, by not being volatilized at a red heat. Before adding the chloride of platinum, a minute quantity of hydrochloric acid should be poured into the liquid to be tested; and it should be evaporated to dryness, at the temperature of 212°: after this, a little cold water being added, the double chloride will appear in small bright yellow crystals. Tartaric acid, precipitates potassium from neutral, or alkaline solutions, as a white granular crystalline precipitate—the bitartrate of potash, which subsides rapidly. If the solution is alkaline, the tartaric acid must be added, until there is an acid reaction. When the solution is dilute, the precipitate does not form immediately: but its formation is accelerated by violent motion. Acid solutions, before being tested, must be neutralized with soda, or its carbonate. The bitartrate of potash is distinguished from that of ammonia, by being more insoluble: also, the salts of ammonia are all volatilized by a red heat —with, or without, decomposition. Since ammonia [254] gives, with bichloride of platinum, and tartaric acid, similar *precipitates*: ammoniacal salts should be removed, by igni-

on, before testing for potash. Alcohol containing a salt potash, burns with a violet flame, unless soda is present.

624. If a salt of potash is attached to a bit of platinum ire, and held in the inner flame of the blow-pipe, unless da is present, the outer flame acquires a violet tint. This ises from the production of potassium, and its subsequent xidation. The glass formed under the blow-pipe, with ickel and borax [587], which should be brownish, becomes, potash is present, of a blue colour.

625. Rhodium:*—*symb.* R; *equiv.* 52·2. It was dis-overed by Wollaston, in 1803: and is found in combina-on with platinum, and palladium—being dissolved out ong with them, with aqua regia. After most of the latinum has been thrown down by sal-ammoniac, and all ie palladium, by cyanide of mercury [594], and both are moved, hydrochloric acid is to be added: and the solu-on is to be evaporated to dryness, to decompose the excess f cyanide of mercury, and change it into a chloride. The sidue must then be reduced to a fine powder, and washed ith alcohol specific gravity 0·837—which dissolves the ouble chlorides of sodium and platinum, of sodium and idium, of sodium and copper, and of sodium and mer-ury, and leaves the double chloride of sodium and rhodium, the form of fine red powder. The latter being washed ith alcohol, is decomposed, by gently heating it in a cur-ent of hydrogen: and the reduced rhodium is separated om the chloride of sodium, with which it was combined, y washing with water.

626. Rhodium, thus obtained, is a black powder; but, hen rendered coherent by pressure, it is white, and has a pecific gravity of 11·0. It is hard, and very brittle. lloyed with steel [529], copper, lead, or platinum, it dis-olves along with them in aqua regia; but, when quite ure, it is insoluble in that fluid, even at a boiling tem-erature. It combines with every metal upon which the xperiment has been made, except mercury. A sixth part f it renders gold much less fusible, but does not sensibly lter its colour.

627. Rhodium forms, with oxygen, protoxide (RO; 0·2); peroxide (R_2O_3; 128·4); and also, it is probable,

* *Rhodon*, a rose, *Gr.*: from the colour of its solutions.

complex oxides, resembling those of iron, and manganese. It forms, with chlorine, protochloride (RCl; 87·67); and perchloride (R_2Cl_3; 210·81), &c.

628. *Tests for Rhodium.*—The most important of the salts of rhodium, are those of the sesquioxide. They are known, in solution, by giving, with potash, after protracted digestion, a greenish-yellow precipitate: with ammonia, and carbonate of ammonia—after some time—a yellow precipitate, consisting of sesquioxide of rhodium and ammonia, soluble in hydrochloric acid. With sulphuretted hydrogen, and hydrosulphuret of ammonia—also, after some time—a dark brown precipitate.

629. The haloid salts of rhodium are red; the oxysalts, yellow, red, or brown.

630. All the salts of rhodium, when heated, are decomposed by dry hydrogen, the metal being reduced.

631. Ruthenium:—*symb.* Ru; *equiv.* 52·1. It was discovered by Professor Clauss: and is obtained from platinum ore—after the platinum, iridium, and osmium are removed—by fusing it with nitre, and keeping it at a white heat for two hours, in a Hessian crucible. Then, while the mass is still hot, it is taken out with an iron spatula: and, after cooling, is reduced to a coarse powder. Distilled water being next added, and the whole having been allowed to rest, the supernatant perfectly clear dark yellow liquid is decanted—but not filtered, since, the filtering paper would decompose it. Afterwards nitric acid is cautiously added, until the alkaline reaction disappears:—this precipitates the oxide of ruthenium, potash, and silicic acid, as a black powder, and the chromate of potash remains in solution. The precipitate having been dissolved in hydrochloric acid, and the solution evaporated until the silex separates, it is diluted with water, and filtered. It cannot be evaporated to dryness, to separate the silex more completely: for the chloride of ruthenium would then be changed into insoluble protochloride.

632. Ruthenium resembles iridium, in appearance. Its specific gravity, is 8·6. Heated in atmospheric air, it combines with oxygen.

633. Ruthenium forms with oxygen, protoxide (RuO; *60·1*); sesquioxide (Ru_2O_3; 128·2); peroxide (RuO_2;

68·1); and ruthenic acid (RuO_3; 76·1). It combines with sulphur, &c.

634. *Tests for Ruthenium.*—Ruthenium, unlike all the other platinum metals, is precipitated by ammonia, as a black oxide, from the aqueous solution of its chloride, at *ordinary temperatures.* This may be reduced, by passing a current of hydrogen over it, at a red heat.

Metallic ruthenium is precipitated as a black powder, when a slip of zinc is inserted in the orange coloured solution of its chloride, acidified with hydrochloric acid. The solution will be indigo blue, until all the metal is thrown down: after which, it will be colourless.

635. SILVER:—*symb.* Ag*; *equiv.* 107·92. This metal was known to the ancients. It is found native: also as a sulphuret, and in combination with various metals:—lead almost always contains it. If uncombined, and in a finely divided state, it is washed out by mercury—from which it is separated by heat. It is obtained from the sulphuret, by roasting it with common salt, in a reverberatory furnace. Chloride of silver, and sulphuret of sodium are formed. $AgS+NaCl=AgCl+NaS$. The chloride being put, along with water, iron, and mercury, into barrels which are made to revolve by machinery, chloride of iron is formed, and the reduced silver is dissolved by the mercury. The mass is then squeezed through leathern bags, the pores of which allow the uncombined mercury to pass through, while the amalgam of silver and mercury is retained. As in the former instance, the mercury is driven off by heat.

636. When silver is procured from galena [541], the combination of lead and silver being melted, and slowly cooled, the lead, which requires a higher temperature for fusion than its combination with silver, solidifies first, and is removed. By repeating this process, much of the lead is got rid of. The remaining silver and lead is then put into a porous dish, made of burned bones, called a *cupel*, and is heated to redness, a current of air being driven across the surface of the metal. This changes the lead into litharge, which is partly absorbed by the cupel, and partly blown away. When the silver becomes suddenly brilliant, it is known to be quite pure. Mercury or copper, also,

* From *argentum*, silver. Lat.

if present, would be oxidized, and removed, during process.

637. Pure silver may be obtained, for chemical purpo by precipitating it from its solution, by means of c copper.

638. Silver is the whitest of all the metals, and is ceeded in brilliancy, only by polished steel. Its spe gravity, is 10·474. It is very malleable, since it may, wit breaking, be hammered into leaves very little more tha 160,000th of an inch in thickness—which is, however, third more than that of gold leaf. Unlike the latter, s leaf does not transmit light, when pure. Silver is soft; but it is hardened, by admixture with copper:— parts silver, and 18 copper, constitute standard silv the mint; but that used, for ordinary purposes, is less p It melts at 1873° Fahrenheit: and if pure absorbs ox during fusion, but gives it out again, when solidifyi which causes the surface to be granulated. Expose the atmosphere, however moist, it is not oxidized; bu very soon covered with a coating of sulphuret—on acc of the sulphuretted hydrogen, generally present in th A small wire, or a thin leaf of silver, will burn in oxy-hydrogen flame. When ignited, by means of the vanic battery, it emits greenish white sparks. Silv soluble in nitric, and, by the aid of heat, in sulphuric

639. It forms, with oxygen, suboxide (Ag_2O; 223· and oxide (AgO; 115·92). The latter, combined ammonia, forms a black powder ($3AgO+NH_3+Ag$)— ammoniuret of silver, which the slightest shock, or fric causes to explode with great violence. Silver forms, peroxide (AgO_2; 123·92). It forms, with chlorine, chl ($AgCl$; 143·39), found native, as "horn silver." compound, which is often produced in testing [333, will yield its metallic silver, if it is placed along with clean iron, or zinc, in a small quantity of water, a sulphuric, or hydrochloric, acid being added: chlori zinc—or iron—and pure silver, being the results. it is fused with common resin, the hydrogen of which comes hydrochloric acid, and escapes. Silver forms, wit dine, iodide (AgI; 234·77). With bromine, bromide (Ag 187·89). With sulphur, sulphuret (AgS; 123·92), &

640. Compounds of Silver, &c.—*Nitrate of silver* (NO_5+AgO). It may be obtained, by dissolving standard silver in nitric acid: then converting all the copper present into black oxide, by evaporation, and the continued application of heat. When this has been completely effected, water of ammonia added to a drop of solution of the salt, will not cause a blue tint. The fused mass is to be dissolved in water, and filtered. Nitrate of silver is an extremely corrosive substance: it rapidly destroys animal tissues, and is much used in surgery, &c. When fused, and cast in moulds, so as to form small sticks, it is termed "lunar* [550; note] caustic." It throws down hydrochloric, hydriodic, hydrobromic, hydrocyanic, hydrosulphuric, iodic, periodic, and bromic acids, from their neutral solutions.

641. *Ammonio-nitrate of silver* ($NO_5+NH_4O+NH_2Ag$), is obtained by cautiously dropping water of ammonia into a solution of nitrate of silver, until the precipitate, at first formed, is redissolved. It must be prepared every time it is required.

642. *Tests for Silver.*—Silver, in solution, is known, by giving, with potash, and ammonia, a light brown oxide, soluble in ammonia:—the presence of ammoniacal salts diminishes the precipitate, or altogether prevents its formation. We must not add ammonia so as to redissolve the precipitate to any extent, as the resulting fulminate of silver, which explodes by friction, or percussion, might become dangerous. It gives, with the alkaline carbonates, a white precipitate, soluble in carbonate of ammonia. With hydrochloric acid, and the soluble metallic chlorides, a white chloride—soluble in ammonia, and changed, by the action of light, to violet, and then black. With iodide of potassium, a canary yellow precipitate. With chromate of potash, a rich brown. With sulphuretted hydrogen, and hydro-sulphuret of ammonia, a brown black sulphuret—soluble in, and decomposed by boiling nitric acid, sulphur being deposited. With ferrocyanide of potassium, a white precipitate: with ferridcyanide of potassium, a reddish brown; and, with chromate of potash, a rich brown. The salts of silver, when mixed with carbonate of soda, and placed on charcoal, are easily reduced by the blow-pipe.

* *Luna*, the moon. *Lat.*

Most metals precipitate silver in the metallic state:—
cury, however, effects this but slowly, giving rise
symmetrical product termed "the tree of Diana."
is precipitated in the metallic state, also, by the sulp
by sulphate of the protoxide of iron—which is peroxi
and, by protochloride of tin, which resolves itself in
chloride, and metallic tin:—the latter, reduces the o
silver, by combining with its oxygen.

643. Sodium:—*symb.* Na;* *equiv.* 22·97. It w
covered by Sir H. Davy, in 1807: and is found, in
bination, most abundantly—being one of the consti
of common salt, &c. It may be obtained, in the sam
as potassium [607]: but more easily, since it do
form a compound with carbonic oxide; nor does th
cess require so high a temperature.

644. Sodium is a brilliant white metal. Its s
gravity, is 0·972. Like potassium, therefore, it float
water. At ordinary temperatures, it may be moulde
the fingers. It melts at 200°, and is vaporized by
heat. It is soon oxidized, by the air: and immediat
water, hydrogen—temporarily combined with soda,
evolved. If it is allowed to move about in that flui
gas produced does not take fire spontaneously, unless
oil of vitriol has been previously added. When th
bule is kept in one place, by fastening it to the side
vessel, or thickening the water with gum or starch, th
becomes heated, and the action is then so energetic, th
gas ignites.

645. Sodium forms, with oxygen, protoxide (
30·97), ordinarily called "soda," and by the Ger
natron: also, peroxide (Na_2O_3; 69·94). With chl
chloride ($NaCl$; 58·44) or "common salt," which
soluble in absolute alcohol, but is soluble, and with
facility, in hot or cold water. With iodine, iodide (
149·82). With bromine, bromide ($NaBr$; 102·94).
fluorine, fluoride (NaF; 41·83). With sulphur, sulp
(NaS; 38·97), &c.

646. Compounds of Sodium, &c.—*Soda* rese
potash very much, and may be obtained in solution
or as a hydrate [612], in the same way as that subs

* From *natron*, the name of a native soda.

647. *Carbonate of soda* (CO_2+NaO), is manufactured, in large quantities, for the use of the soap boiler, &c., by adding sulphuric acid to common salt [356]: and heating the resulting sulphate to redness, along with charcoal—or coke—and carbonate of lime. The oxygen of the sulphuric acid, forms carbonic oxide, with the carbon: and the resulting sulphuret of sodium, forms, with the carbonate of lime, sulphuret of calcium, and carbonate of soda. $(SO_3+NaO)+4C=NaS+4CO$: then, $NaS+(CO_2+CaO)=CaS+(CO_2+NaO)$. The carbonate of soda is dissolved out, with water. Sometimes, the common salt is decomposed, by carbonate of ammonia; and, when the resulting carbonate of soda has been separated, the sal-ammoniac is reconverted into carbonate, by carbonate of lime. If this process is employed, the soda salt contains no sulphur; but ammonia is wasted. Carbonate of soda is obtained pure, very conveniently, by heating the best commercial bicarbonate of soda to redness, for some time.

648. *Hyposulphite of soda* (S_2O_2+NaO), may be made, by transmitting sulphurous acid through a solution of bicarbonate of soda; and boiling the result with sulphur. Hyposulphite of soda is produced, and carbonic acid is evolved;—$(2CO_2+NaO)+SO_2+S=S_2O_2+NaO)+2CO_2$.

649. *Sulphate of soda* (SO_3+NaO), may be obtained, by neutralizing carbonate of soda with dilute sulphuric acid.

650. *Phosphate of soda* ($PO_5+2NaO+HO$), may be formed, by adding carbonate of soda to soluble superphosphate of lime [320], as long as effervescence continues:—phosphate of lime is thrown down, and phosphate of soda remains in solution. The sulphate of lime, which also is present, causes carbonate of lime to be found in the precipitate, and sulphate of soda in the solution:—the latter, is got rid of by recrystallization. The crystals of this salt, without losing their form, abandon, it is probable, ten out of their twenty-four atoms of water, if exposed to the air.

651. *Microcosmic salt* or phosphate of soda and ammonia ($PO_5+NaO+NH_4O+HO$), is formed by dissolving in hot water, and mixing together, six parts of phosphate of soda, and one of sal-ammoniac. On cooling, crystals

are produced, which effloresce in the air. They are freed from the chloride of sodium, which adheres to them, by recrystallization. And, being dried and pulverized, they may be preserved in a bottle for use. This salt, when heated strongly, loses the elements of water, and ammonia: and the residuum, which consists of monobasic phosphate of soda, and free phosphoric acid, is capable of fusing almost every chemical compound. Microcosmic salt, produces results similar to borax (triborate of soda), but often more marked.

652. *Tests for Sodium.*—When the solution of a salt gives no precipitate with a carbonate, it is alkaline; and, if not recognised, by the proper tests, as ammonia [254] or potash [623], it must be a salt of sodium. Besides, antimoniate of potash, with the neutral or alkaline salts of sodium, affords a white crystalline antimoniate ($Sb\dot{O}_2 + Na\dot{O}$), even if potassium also is present—which, however, ought not to be the case. When the solution is dilute, it is formed very slowly: but its production is accelerated by violent motion; and it will be perceived on the vessel, if of glass, wherever it is rubbed with a glass rod. Should the liquid to be tested contain carbonate of potash, the carbonic acid must previously be driven off, by hydrochloric acid. Acid solutions must be rendered slightly alkaline, by potash: or the antimoniate of potash will be decomposed, hydrated antimonic acid, or bi-antimoniate of potash, being precipitated. Tartaric acid produces a precipitate, only in highly concentrated solutions containing sodium: and the bitartrate which, after some time, separates, is in the form of needles and columns—while bitartrate of potash, is in the form of grains. If a small quantity of water is added to a salt of soda, and then alcohol, when the latter is ignited, the flame is a deep yellow, whether potash [623] is present, or not. If a salt of soda, even when mixed with a large quantity of potash [624], is heated on a platinum wire, in the inner flame of the blow-pipe, the outer flame is intensely yellow—on account of the combustion of the sodium, which is reduced by the inner flame.

653. STRONTIUM:*—*symb.* Sr; *equiv.* 43·65. It was

* Because the mineral containing it was found at Strontian, in *Scotland.*

discovered by Davy, in 1807: and is obtained from the earth strontia—which greatly resembles baryta, and, at first, was confounded with it—by the method used for obtaining barium [444].

Strontium is very like barium, but not so brilliant. It oxidizes in the air: and decomposes water, oxide being produced, and hydrogen being liberated.

654. Strontium forms, with oxygen, protoxide (SrO; 51·65) or "strontia," used in pyrotechny for the production of a beautiful red fire: and peroxide (SrO_2; 59·65). With chlorine, chloride ($SrCl$; 79·12). With iodine, iodide (SrI; 170·50). With fluorine, fluoride (SrF; 62·51). With sulphur, sulphuret (SrS; 59·65), &c.

655. *Tests for Strontium.*—Strontium, in solution, is known, by giving, with sulphuric acid, and the soluble sulphates, a more soluble precipitate (SO_3+SrO) than barytes. It gives, with oxalic acid, a white oxalate ($\overline{O}+SrO+Aq$)—and still more easily, if ammonia is added. It affords, with chromate of potash, on boiling, a yellow chromate (CrO_3+SrO). Alkaline carbonates, produce a white carbonate (CO_2+SrO)—which is not completely precipitated, in acid solutions, until heat is applied. Solutions of gypsum, cause a precipitate at once, with barytes: but, only after some time, with strontia. The latter may be separated from barytes, in the form of chloride, by adding an excess of hydrofluosilicic acid—which throws down, after being at rest for some hours, silico-fluoride of barium, the strontium being left in the solution. It may be separated from lime, when in the form of nitrate—excess of nitric acid being avoided—by evaporating to dryness, and digesting for some hours, with absolute alcohol, which dissolves the nitrate of lime, but not the nitrate of strontia. When alcohol, in which soluble salts of strontia have been digested, is set on fire, the flame is of a carmine red colour. Chloride of strontium, heated on platinum wire, at the apex of the blue flame of the blow-pipe, tinges the entire flame of a deep crimson:—but this effect is prevented, by the presence of chloride of barium. As the assay fuses, the colour disappears—which distinguishes it from chloride of lithium.

656. TELLURIUM:*—*symb.* Te; *equiv.* 64·25. It was

* From *tellus*, the earth. *Lat.*

inferred to exist, by Müler, in 1782; but its existence was proved and its name was given to it, by Klaproth, in 1798. It has been found in the metallic state, combined with gold, silver, &c., in the gold mines of Transylvania—but only in small quantities. It is white, brilliant, and of a lamellated texture. Its specific gravity, is 6·26. It crystallizes easily, is brittle, and as fusible as antimony. It burns under the blow-pipe, the flame being blue, bordered with green. It is rapidly oxidized, by nitric acid; and gives to sulphuric acid a deep purple colour. It has a very close analogy to sulphur.

657. Tellurium forms, with oxygen, tellurous (TeO_2; 80·25), and telluric (TeO_3; 88·25) acids—both of which have different properties, according as they are in the hydrous, or the anhydrous state. It forms, with chlorine, chloride ($TeCl$; 99·72); and bichloride $TeCl_2$; 135·19). With hydrogen, telluretted hydrogen (TeH; 65·25) or hydro-telluric acid, &c.

658. *Tests for Tellurium.*—Tellurium, as tellurous acid, is recognised, in solution, by giving, with the alkalies, and alkaline carbonates, a white precipitate—soluble in the latter, and in caustic potash. With sulphuretted hydrogen, a brown precipitate, soluble in hydro-sulphuret of ammonia. It is precipitated, in the metallic state, as a black powder, by sulphurous acid, and the alkaline sulphites: and by metallic zinc, &c.

659. TERBIUM:—*symb.* *Tb.* The oxide of this metal was discovered by Mosander—being considered the principal ingredient in the second, or intermediate precipitate, obtained from yttria [500]. Nothing is yet known of its properties. Its oxide probably forms pale red salts.

660. THORIUM:—*symb.* *Th*;* *equiv.* 59·83. It was discovered, by Berzelius, in 1829: and is obtained from the chloride, by the action of potassium—the decomposition being accompanied by a slight detonation. After the mass has been washed, thorium is found, as a heavy powder of a deep leaden gray colour. Triturated in an agate mortar, it becomes of an iron gray; and has a metallic lustre. Thorium is not affected by water, either hot or cold, nor by caustic alkalies—even at a boiling temperature. Heated

* From *Thor*, a Saxon deity.

in the air, it burns as brilliantly as phosphorus does in oxygen. Nitric acid affects it very little; sulphuric acid dissolves it slowly, but hydrochloric with great rapidity, hydrogen being disengaged.

661. Thorium forms, with oxygen, oxide ($Th O$; 67·83) called "thorina," the sulphate of which, unlike all other oxidized bodies, is precipitated by boiling, and redissolved by cooling. It forms compounds with chlorine, &c.

662. *Tests for Thorium.*—Thorina is thrown down from solutions of this metal, by the caustic alkalies, as a hydrate, which rapidly absorbs carbonic acid from the atmosphere. It is precipitated by the alkaline carbonates—in which it is insoluble, whether as an oxide, carbonate, or subsalt. It is distinguished from alumina, and glucina, by being insoluble in caustic potash: from yttria, by forming with sulphate of potash, a double salt insoluble in a cold solution of sulphate of potash. It is distinguished from zirconia, by the latter being, after precipitation from a hot solution of sulphate of potash, almost insoluble in water, and the acids: and by being precipitated, with ferrocyanide of potassium, which is not the case with zirconia.

663. Tin: *symb.* Sn:* *equiv.* 58·82. It was known to the ancients. The Phœnicians were well acquainted with the tin of Cornwall. Before the method of working iron was discovered, an exceedingly hard compound of copper and tin was used for cutting instruments:—but its utility was greatly diminished, by its being incapable of receiving a *temper* [533], like steel. Swords, &c., of this material, are frequently found in Ireland, and other countries. Tin is obtained from the native peroxide, by heating it with charcoal: and it is still further purified, by "liquation"—that is, raising the metal to such a temperature, as causes the pure or "grain tin" to melt, the impurities being left in the residual mass, called "block tin."

664. Tin is white, and brilliant. Its specific gravity, is 7·291. Its surface soon becomes tarnished, by exposure to the atmosphere: yet it is very slowly oxidized by air, and moisture—and is, therefore, used to protect other metals. For this purpose, iron, and copper, are frequently coated with it—particularly the former, which then constitutes

* *Stannum*, tin. *Lat.*

what is ordinarily termed "tin," and is so commonly employed for domestic purposes. It is very malleable; and may easily be reduced to leaves, the 2000th part of an inch in thickness. Thin leaves of it, under the name of "tinfoil," are used for electrical [elect. 47], and other purposes. Tin is soft, and inelastic, and, when bent, emits a peculiar crackling noise: it is rendered more brittle, by fusion with bismuth. It melts at 442°, and its surface, if exposed to the atmosphere, is then covered with a gray powder. Like lead, when heated too near its melting point, it is brittle. It burns with a colourless flame, at a white heat, peroxide being formed. Strong sulphuric acid, with the aid of heat, dissolves half its weight of tin. It is soluble, also, in hot nitric acid: but almost all of it falls down again, as peroxide. Oxide of tin is formed, when [120] nitrate of copper is wrapped up in tinfoil. Hydrochloric acid dissolves it, and then emits fumes. Added, by small quantities at a time, to aqua regia, it produces a solution, which is used, by dyers, to heighten the colours of cochineal, &c., so as to change them, from crimson to bright scarlet.

665. Tin forms, with oxygen, protoxide (SnO; 66·82) —remarkable, from the tendency of its salts to absorb oxygen, which renders them powerfully deoxidizing agents: sesquioxide (Sn_2O_3; 141·64); and peroxide (SnO_2; 74·82). With chlorine, protochloride ($SnCl$; 94·29), and perchloride ($SnCl_2$; 129·76). With iodine, protiodide (SnI; 185·67), and biniodide (SnI_2; 312·52). With sulphur, protosulphuret (SnS; 74·82); sesquisulphuret (Sn_2S_3; 165·64): and bisulphuret (SnS_2; 90·82), &c.

666. Compounds of Tin, &c.—*Peroxide of tin* (SnO_2), is the most infusible of all the metallic oxides. It constitutes, when melted with glass [385], a white enamel. Acting as a feeble acid, it forms a class of salts called *stannates*. It exists in two states:—when precipitated from persalts, by alkalies, it dissolves easily, in potash, and the acids: which is not the case, when it is obtained by acting on tin with nitric acid. The soluble is changed into the insoluble peroxide, by ignition; and the insoluble, into the soluble, by fusion with carbonate of soda.

667. *Protochloride of tin* ($SnCl$), may be obtained by melting pure tin in an iron spoon: triturating the fused

mass, and boiling an *excess* of it, along with concentrated hydrochloric acid, in a flask: then diluting the result with four or five times its bulk of water, acidulated with hydrochloric acid, and filtering. It is to be kept in a well-closed bottle, containing pieces of metallic tin:—without this precaution, it would be changed into perchloride.

668. *Tests for Tin.*—The protosalts of tin are decomposed by heat. Water added to solutions of neutral protosalts, causes milkiness—an insoluble basic salt being formed: hydrochloric acid, renders the solution again clear. Potash, and ammonia—as also their carbonates—throw down from solutions of the protosalts, a white bulky hydrated protoxide ($SnO+HO$), that dissolves in potash. If the potash solution is heated, the protoxide is changed into peroxide, which remains dissolved, and metallic tin, which is precipitated as brown flakes. $2SnO=SnO_2+Sn$. Sulphuretted hydrogen produces, in neutral, and acid solutions, and hydrosulphuret of ammonia, in all, a dark brown protosulphuret, soluble in potash, and in the alkaline hydrosulphurets—particularly in those which contain excess of sulphur. The solution of this precipitate, in sulphuretted hydrosulphuret [253] of ammonia, affords, with acids, yellow bisulphuret of tin, along with sulphur. If it is boiled with nitric acid, it is changed into insoluble peroxide. Perchloride of mercury, in excess, throws down, from solutions of the protochloride, or protoxide of tin, a white precipitate:—the latter is protochloride of mercury, the tin having taken half its chlorine from that metal. Perchloride of gold throws down, from the same solutions, if nitric acid is added, a purple precipitate—the "purple of Cassius," which is insoluble in hydrochloric acid, and is, probably, a mixture of peroxide of tin, and metallic gold. Ferrocyanide, and ferridcyanide, of potassium throw down white precipitates. The salts of the protoxide, exposed to the atmosphere, are changed to those of the peroxide.

669. The persalts of tin are decomposed at a red heat. Potash, ammonia, and their carbonates, thrown down from solutions, contain the persalts, a white hydrated peroxide (SnO_2+HO), slightly soluble in ammonia, but easily so in potash. Sulphuretted hydrogen, and hydrosulphuret of ammonia, throw down from acid, and neutral, solutions,

a yellow bisulphuret, which is soluble in potash, in alkaline sulphurets, and in boiling hydrochloric acid; and is changed into peroxide, by boiling with nitric acid. Metallic zinc throws down metallic tin, in grayish white metallic spangles, or as a spongy mass, from solutions of the perchloride, or of persalts—not containing free nitric acid. If the latter is present, the precipitate will consist of hydrated peroxide, or of that substance and metallic tin.

670. TITANIUM:* *symb.* Ti; *equiv.* 24·33. It was discovered by Gregor, in 1791: and received its name, from Klaproth. It has been found, as titanic acid, in many minerals. It occurs in clay iron stone:—and, therefore, in the smelting of iron, it is present in the slags, crystallized in very hard and brilliant cubes. It is obtained, by igniting the titanate of iron with sulphur. The results are sulphurous acid, sulphuret of iron, and free titanic acid —which remain behind, when the sulphuret of iron is dissolved by hydrochloric acid. The titanic acid is mixed with lampblack, and chlorine is passed through the mixture, heated to redness:—carbon unites with the oxygen of the acid, and chloride of titanium is formed. The latter is a colourless, and very volatile liquid, which fumes in the air: and combines with water, so violently as to cause explosion. This perchloride, by absorbing perfectly dry ammonia, forms a white substance ($TiCl_2+NH_3$), which if heated to redness, gives sal-ammoniac, nitrogen, and metallic titanium—the chlorine being removed by the hydrogen of ammonia.

671. Titanium, thus obtained, is in the form of a deep blue powder, which is liable to take fire, if exposed to the atmosphere while warm. In the solid form, it is of a bright copper colour. Its specific gravity, is 5·3. It is nearly infusible. It is not acted on, by the air: but is oxidized, slowly, by melted nitre. It is dissolved, only by a mixture of nitric and hydrofluoric acids.

672. Titanium forms, with oxygen, oxide of titanium (TiO; 32·33); and titanic acid (TiO_2; 40·33). With chlorine, a volatile bichloride ($TiCl_2$; 95·27). With sulphur, bisulphuret (TiS; 56·33), &c.

673. *Tests for Titanium.*—Titanium is known, by

* From the *Titans* of heathen mythology.

giving, with ammonia, a white gelatinous hydrate, soluble in acids—and, to a certain extent, in alkaline carbonates. With ferrocyanide of potassium, a red brown precipitate. Titanic acid is precipitated, as a white powder, by sulphate of ammonia—with the aid of heat. Its solution in hydrochloric acid affords, with tincture of galls, an orange precipitate. The solution of an alkaline titanate in hydrochloric acid gives, with a bar of metallic zinc, or iron, a blue or violet oxide, which gradually alters to white:—the nascent hydrogen changes the acid to oxide, by combining with an atom of its oxygen. Tantalic [487] is distinguished from titanic acid, by the solubility of its hydrate, in caustic potash; and being thrown down, from its solution in hydrochloric acid, by sulphuric acid.

674. TUNGSTEN:*—*symb.* W;† *equiv.* 94·8. It was discovered by D'Elhuyar, in 1781: and is obtained, by boiling native tungstate of lime with hydrochloric acid—which dissolves out the lime, and leaves the tungstic acid, as a yellow powder. The latter, at a full red heat, is reduced by hydrogen.

675. Tungsten is of a grayish white colour. Its specific gravity, is 17·5. It is very hard, brittle, and infusible:—it melts, however, before the oxy-hydrogen blow-pipe. It is very insoluble in acids—which is the case, also, with its oxide. Acted upon, by nitre, it becomes tungstic acid:—the latter is produced, likewise, when the metal is heated to redness, in atmospheric air. Digested with a strong solution of caustic potash, it forms tungstate of potash, hydrogen being disengaged.

676. Tungsten forms, with oxygen, deutoxide (WO_2: 110·8): blue oxide (W_2O_3; 213·6); and tungstic acid (WO_3; 118·8). It forms with chlorine, bichloride (WCl_2; 165·74), and perchloride (WCl_3; 201·21). With sulphur, bisulphuret (WS_2; 126·8); and persulphuret (WS_3; 142·8), &c.

677. If deutoxide of tungsten is combined with soda, a substance ($2WO_2+NaO$) is produced which greatly resembles gold. It may be obtained, by adding to fused

* *Tung sten*, heavy stone, *Swed.*; on account of the density of its ores.

† From *Wolfram*, a mineral in which it is found.

tungstate of soda, as much tungstic acid as it can dissolve, exposing the result, at a full red heat, to a current of hydrogen, and then dissolving out the tungstate of soda. The residue will consist of brilliant scales, and cubes, which are like gold in colour: are insoluble in alkalies, or in acids—including even aqua regia, that [358] dissolves gold itself: and are acted upon, only by strong hydrofluoric acid.

678. *Tests for Tungsten.*—When zinc is immersed in acid solutions of tungstic acid, it produces a beautiful blue colour—on account of the formation of tungstic oxide. If a tungstate is decomposed by an acid, in the presence of hydrosulphuret of ammonia, a blackish brown sulphuret of tungsten (WS_3) is precipitated.

679. URANIUM:*—*symb.* U: *equiv.* 60. It was discovered by Klaproth, in 1789: and may be obtained from *pitchblende*—a Saxon mineral, consisting of protoxide of uranium and oxide of iron, mixed with the sulphurets of lead and copper—by heating it to redness: reducing it to a fine powder: and digesting it in a smaller quantity of nitric acid than will dissolve the whole of the mineral, mixed with three or four parts water. This changes the protoxide of uranium into peroxide, which combines with the nitric acid, to the almost total exclusion of the iron. The lead, and copper, present in the solution, are then thrown down by sulphuretted hydrogen: and the excess of the latter, is expelled by boiling. After this, the solution is concentrated by evaporation, and left to crystallize. The nitrate separates, in the form of flattened, four-sided prisms, of a beautiful lemon colour; which, being heated to redness, are changed to yellow oxide: and are converted, by a strong heat, into sesquioxide. The latter, is reduced to protoxide—long considered as the metal itself—by mixing it with charcoal, and passing chlorine over the mixture, strongly ignited. This forms protochloride, which, being acted on with potassium, gives metallic uranium.

680. Uranium resembles silver: and is malleable. It is very combustible: and, when in contact with acids, decomposes water—hydrogen being evolved.

* From the planet Uranus, discovered in the same year.

681. Uranium forms, with oxygen, protoxide (UO; 68), which, with a double atomic weight (U_2O_2), has, under the name of *uranyle*,* been considered as the radical of the ordinary salts of uranium. It forms also, sesquioxide (U_2O_3; 144); uranoso-uranic oxide ($UO + U_2O_3$; 212); and peroxide of uranium (U_2O_5; 160) which, it is probable, should be termed uranic acid—since, though it changes paper, stained red with an infusion of logwood, to blue, it reddens moistened turnsole paper. This oxide is used to give glass a lemon colour. Uranium combines also with chlorine, &c.

682. *Tests for Uranium.*—Uranium, in solution, is thrown down by the caustic alkalies, as a greenish hydrated sesqui-oxide; which, by absorbing oxygen, and becoming peroxide, rapidly changes to yellow. The hydrated sesquioxide dissolves in acid, forming yellow solutions: heated to about 300°, it becomes anhydrous, and of a bright brick colour:—at a higher temperature, it becomes uranoso-uranic oxide, of a deep gray colour. Heated on platinum wire with microcosmic salt, in the oxidating flame of the blow-pipe, it melts into a clear yellow glass, which on cooling becomes green. Uranium gives, with ferrocyanide of potassium, a red-brown: and, with ferridcyanide, a brown precipitate.

683. VANADIUM:†—*symb.* V; *equiv.* 68·66. It was discovered by Sefström, in 1830: and may be obtained, from a mineral, which is found at Wanlockhead, in Scotland—and consists, chiefly of vanadiate of lead—by dissolving it in nitric acid: precipitating the lead, and any arsenic present, by sulphuretted hydrogen—which deoxidizes the vanadic acid: and evaporating the blue solution to dryness—which reproduces the acid. The residue is then dissolved in ammonia: and the resulting vanadiate of ammonia—which is insoluble in a strong solution of sal-ammoniac—is precipitated, by adding to the solution containing it, a larger piece of sal-ammoniac than it can dissolve. This separates the vanadic from arsenic acid, if

* The termination *yle* is derived from *ulē*, the material of which any thing is made. *Gr.*—We shall find it employed very frequently, hereafter.

† From *Vanadis*, a Scandinavian deity.

any remains: and, also, from phosphoric and hydrochloric acid. The precipitated vanadiate is washed, first in a solution of sal-ammoniac, and then in alcohol, specific gravity 0·86: and is afterwards heated to below redness, in an open platinum crucible, the mass being kept well stirred, until it acquires a dark red colour. The resulting vanadic acid is changed, by means of charcoal, or hydrogen, and the application of heat, into the protoxide, which is a fine black powder, when it is broken down. This powder is mixed with charcoal, and a current of dry chlorine is transmitted through the mixture, heated to low redness. Terchloride passes over, in vapour, and is condensed into a yellow liquid, from which the free chlorine may be removed by a current of dry air—water, or moist air would convert it into hydrochloric, and vanadic acid. The terchloride being introduced into a bulb, which has been blown in a barometer tube, dry ammoniacal gas is passed into it, and is rapidly absorbed—a white saline mass being produced. When this is heated, the sal-ammoniac is expelled, and the residue is vanadium.

684. Vanadium, thus obtained, has a strong metallic lustre, and resembles molybdenum in appearance:—on attempting to remove it from the bulb, it falls into powder. It is not oxidated, by water: but acquires a reddish tint, by exposure to the air. It is soluble in nitric acid, and aqua regia—the solution being of a dark blue colour. It is not dissolved by sulphuric, hydrochloric, or hydrofluoric acid—whatever may be the temperature: nor is it oxidized by boiling with caustic potash, nor by the alkaline carbonates, at a red heat.

685. Vanadium forms, with oxygen, protoxide (VO; 76·66); deutoxide (VO_2; 84·66); and vanadic acid (VO_3; 92·66). With chlorine, bichloride (VCl_2; 139·60); and terchloride (VCl_3; 175·07). With bromine, bibromide (VBr_2; 228·60). With sulphur, bisulphuret (VS_2; 100·66); and tersulphuret (VS_3; 116·66), &c.

686. *Tests for Vanadium.*—Oxide of vanadium is thrown down from its solution, by potash, as a white hydrate, soluble in excess. By hydrosulphuret of ammonia, as a brownish black precipitate, soluble in excess, the solution being purple.

687. Vanadic acid, in solution, gives, with hydrosulphuret of ammonia, a brown tersulphuret, soluble in excess —the solution being brown. With ferrocyanide of potassium, a green precipitate. With chloride of barium, a bulky orange yellow precipitate, not quite insoluble in water. With sal-ammoniac, a white flocculent vanadiate of ammonia, which is insoluble in hydrochloric acid.

Oxides of vanadium give, with borax, or microcosmic salt, in the outer flame of the blow-pipe, a yellow, in the inner flame, a green bead. Vanadic acid gives, with borax, or microcosmic salt, a brown glass—which becomes green, on cooling.

688. YTTRIUM:*—*symb.* Y; *equiv.* 32·25. It was discovered by Wöhler, in 1828: and is found in the Bohemian garnet, also in some rare Swedish minerals. It is obtained, by precipitating yttria, from its solution, with caustic potash; and heating the last portion of the precipitate [500 and 659], along with potassium.

689. Yttrium is of a grayish black colour, of a scaly texture, and brittle. It is not acted upon by air, or moisture; but it burns splendidly in air—and still more so in oxygen. It is soluble in sulphuric acid, &c.: and partially so, in caustic potash.

690. Yttrium forms, with oxygen, oxide (YO; 40·25)—the earth yttria. It combines, also with sulphur, selenium, &c.

691. *Tests for Yttrium.*—Yttria is thrown down by potash, as a white precipitate. It is precipitated, also, by the alkaline carbonates, the resulting carbonate being soluble in excess, and dissolving easily in carbonate of ammonia—crystals of the double carbonate of ammonia and yttria may be obtained from the solution. Phosphate of soda gives a white precipitate, which is soluble in hydrochloric acid, but is reprecipitated, by boiling. Ferrocyanide of potassium, gives a white precipitate.

692. ZINC:†—*symb.* Zn; *equiv.* 32·53. It was first mentioned by Paracelsus, in the sixteenth century; but was probably known long before. It is found abundantly

* Because obtained from an earthy substance, found at Ytterby, in Sweden.

† *Zinken*, nails. *Ger.*:—from its frequently assuming a form, somewhat resembling nails.

in nature, as "zinc blende," a sulphuret: and as "calamine," a carbonate, or silicate. It is obtained from the native carbonate, by heating with carbonaceous matter:—the carbonic acid is driven off, and the oxygen of the residual oxide combines with the carbon: the zinc is volatilized by the high temperature, and is received in water. Zinc is obtained by methods very similar to those which are used, in procuring lead, and cadmium, from their ores. That of commerce generally contains carbon, iron, &c.:—it may, however, be purified by redistillation: the first part of the product, containing the cadmium, and arsenic, being rejected.

693. Zinc is a brilliant bluish white metal, of a crystalline texture. Its specific gravity, is 7·0. It is hard: and, near the point of fusion, is very brittle. Between 210° and 300°, it is malleable, and ductile, unless it contains more than one and a-half per cent. of lead, which renders it brittle. It melts at 773°, and is volatilized, at a full red heat. Like the other very fusible metals, it is conveniently granulated by pouring it, in the fluid state, through a moistened broom. Fused, in open vessels, it is oxidated, forming "flowers of zinc." If it is heated to redness, in a covered crucible, and the cover is suddenly removed, it burns with a brilliant white light:—the product is an exceedingly light substance, which has been termed "philosophical wool," and "white nothing." Exposed to air and moisture, it is soon covered with a gray coating of suboxide, which greatly protects it from further action. When pure [gal. 16], it is not acted upon by sulphuric acid, except in contact with another metal. It dissolves rapidly in nitric, and in hydrochloric acid, &c.: and generally leaves a black residue, which is charcoal taken up by it in the smelting.

694. Zinc forms, with oxygen, oxide (*Zno*; 40·53), which is lemon coloured while hot. With chlorine, chloride (*ZnCl*; 68). With iodine, iodide (*ZnI*; 159·38). With bromine, bromide (*ZnBr*; 112·5). With sulphur, sulphuret (*ZnS*; 48·53), &c.

695. Compounds of Zinc, &c.—We have already mentioned [492] some very important compounds of zinc with *other metals*, which are extensively used in the arts.

Chloride of zinc ($ZnCl$), may be obtained by dissolving zinc in hydrochloric acid.

696. *Tests for Zinc.*—Zinc is precipitated from its solutions, by potash, or ammonia, as a white hydrate ($ZnO+HO$), soluble in excess. The alkaline carbonates, throw down a white basic carbonate [$2(CO_2+ZnO)+3(ZnO+HO)$], soluble in potash, ammonia, and carbonate of ammonia. Ammoniacal salts, prevent the formation of this precipitate: or, being afterwards added, dissolve it—forming double salts of zinc and ammonia. Sulphuretted hydrogen throws down, from neutral solutions, and hydrosulphuret of ammonia from all that are not very acid, a white sulphuret (ZnS), soluble in hydrochloric, nitric, or dilute sulphuric acid. Ferrocyanide of potassium, causes a white gelatinous precipitate, insoluble in hydrochloric acid. Ferridcyanide of potassium, a yellowish red precipitate, soluble in hydrochloric acid.

If oxide of zinc, either free, or in combination, is moistened with a solution of protonitrate of cobalt, and is then heated with the blow-pipe, an infused mass—consisting of oxide of zinc, and protoxide of cobalt—of a fine green colour, will be obtained.

697. ZIRCONIUM:*—*symb.* Zr; *equiv.* 33·67. It was procured by Berzelius, in 1824, from the zircono-fluoride of potassium (the double fluoride of zirconium and potash), in the same way as silicon is obtained [373] from the silicofluoride of potassium.

698. Zirconium is a black powder which, even when pressed, has only a doubtful metallic lustre: and has not, as yet, been found, in any circumstances, to conduct electricity. It takes fire in the atmosphere, at a temperature below incandescence. Boiling in water does not alter it. It dissolves, with facility, in hydrofluoric acid:—and no other acid has much effect upon it.

Zirconium forms, with oxygen, oxide (Zr_2O_3; 91·34), or "zirconia." It combines also, with sulphur, &c.

699. *Tests for Zirconium.*—Zirconia is thrown down, by potash, and ammonia, as a white precipitate:—the ammonia sometimes gives a subsalt, instead of the sesquioxide.

* So called, from one of the names by which the jargon, a stone of Ceylon, resembling the diamond, is known.

Alkaline carbonates throw down a carbonate, slightly soluble in excess. Ferrocyanide of potassium, causes a white precipitate. When its solution is neutralized with potash, zirconia, like thorina [662] forms, with sulphate of potash, a white double salt, insoluble in a saturated solution of the sulphate. But it is distinguished from thorina, by emitting a glaring white light, during ignition:—zirconia, also, is much heavier than thorina.

700. COMPORTMENT OF THE METALS, WITH REAGENTS.—The following is a synopsis of the characters, by which the various metals may be distinguished from each other; and will probably be found to save considerable trouble. Those which give precipitates that are soluble in excess [47], are marked with a star. And when the precipitate has any peculiar characteristic, reference is made to the paragraph in which it is described—

	Colours of precipitates.
Acetate of lead gives, with—	
Chromium, as chromic acid, a . . .	*Yellow.*
Ammonia gives, with—	
Aluminum* [434], ...	*White.*
Antimony, as protosalt, ...	
Bismuth	
Cadmium*	
Cerium [471], ...	
Copper,* as subsalt [496], . . .	
Donarium†	
Glucinum	
Iron, as protosalt, ammoniacal salts not being present [537], ...	
Lanthanum	
Lead,* not as acetate, ...	
Magnesium—unless the solution is acid, or an ammoniacal salt is present [558], . .	
Manganese, as protosalt—sal-ammoniac not being present [563], ...	
Mercury, as persalt, ...	
Tellurium, as tellurous acid, . . .	
Thorium	
Tin, as protosalt, ...	
Titanium	
Zinc*	
Zirconium [699], ...	

† The precipitate changes to yellow, and then to yellowish red.

	Colours of precipitates.
Ammonia gives, with—	
Gold, in tolerably concentrated solutions [509],	
Platinum,* if the solution is not too dilute, and free hydrochloric acid is present,	*Yellow.*
Rhodium, as sesquioxide—after some time,	
Cobalt,* much sal-ammoniac not being present [482],	
Copper,* as black oxide—sometimes [497],	*Blue.*
Chromium,* as sesquioxide [476],	
Copper,* as black oxide—sometimes [497],	
Nickel,* unless an ammoniacal salt, or free acid, is present [586],	*Green.*
Uranium [682],	
Iron, as peroxide,	*Brown.*
Silver*—ammoniacal salts should not be present,	
Mercury, as subsalt,	
Molybdenum, as molybdous oxide,	*Black.*
Ruthenium, as aqueous solution of chloride [634],	
Ammonio-nitrate of silver gives, with—	
Arsenic,* in acid solutions, a	*Yellow.*
Ammonio-sulphate of copper gives, with—	
Arsenic, in acid solutions, a	*Green.*
Antimoniate of potash gives, with—	
Sodium, in neutral or alkaline solutions, which are not too dilute—potash should not be present, as *carbonate* [652], a	*White.*
Bichloride of platinum gives, with—	
Potash—any ammonia present having been removed [623], a little hydrochloric acid being poured in before the re-agent, the liquid being evaporated to dryness at 212°, and finally the residue being treated with a little cold water—a	*Yellow.*
Carbonate of ammonia gives, with—	
Aluminum	
Antimony, as protosalt,	
Bismuth	
Glucinum	
Lanthanum	
Lead	*White.*
Manganese, as protosalt,	
Silver*	
Strontium—the solution should not be acid [655],	
Tellurium,* as tellurous acid,	
Thorium	

	Colours of precipitates.
Carbonate of ammonia gives, with—	
Tin, Yttrium*, Zinc*, Zirconium*	*White.*
Rhodium, as sesquioxide, after some time, a	*Yellow.*
Copper,* as black oxide—sometimes a	*Blue.*
Copper,* as black oxide—sometimes, Nickel*	*Green.*
Cobalt [482], a	*Red.*
Molybdenum,* as molybdous oxide, a	*Black.*
Carbonate of potash gives, with—	
Aluminum, Antimony, as protosalt, Bismuth [456], Cadmium—ammoniacal salts should not be present, Glucinum*, Lanthanum, Lead, Magnesium, in neutral solutions, ammoniacal salts not being present, and the liquid being boiled [558], Manganese, as protosalt, Silver, Strontium—the solution should not be acid, Tellurium,* as tellurous acid [658], Thorium, Tin, Yttrium*, Zinc—ammoniacal salts should not be present, Zirconium*	*White.*
Nickel, a	*Green.*
Cobalt [482], a	*Red.*
Mercury, as persalt—ammoniacal salts not being present [574], a	*Brown.*
Molybdenum,* as molybdous oxide, a	*Black.*
Carbonate of soda gives, with—	
Aluminum, Antimony, as protosalt, Barium, Bismuth [456], Cadmium—ammoniacal salts should not be present, Glucinum*, Lanthanum, Lead	*White.*

	Colours of precipitates.
Carbonate of soda gives, with—	
Manganese, as protosalt,	*White.*
Silver	
Strontium—the solution should not be acid,	
Tellurium,* as tellurous acid,	
Thorium	
Yttrium*	
Zinc—ammoniacal salts should not be present,	
Zirconium*	
Nickel, a	*Green.*
Cobalt [482], a	*Red.*
Mercury, as persalt—ammoniacal salts not being present [574], a	*Brown.*
Chloride of barium gives, with—	
Chromium, as chromic acid,	*White.*
Molybdenum, as molybdic acid,	
Vanadium, as vanadic acid [687], a	*Yellow.*
Chloride of calcium gives, with—	
Arsenic, as arsenious acid, a	*White.*
Chloride of potassium gives, with—	
Platinum,* in a solution, not too dilute, and free hydrochloric acid being present, a	*Yellow.*
Chloride of sodium gives, with—	
Lead	*White.*
Mercury, as subsalt,	
Silver	
Chromate of potash gives, with—	
Bismuth	*Yellow.*
Lead	
Strontium, the liquid being boiled,	
Mercury, as subsalt, a	*Red.*
Copper, as black oxide,	*Brown.*
Silver	
Cyanide of potassium gives, with—	
Cobalt*	*White.*
Palladium	
Copper,* as black oxide, a	*Green.*
Nickel,* a	*Yellow.*
Ferridcyanide of potassium gives, with—	
Tin, as protosalt, a	White.
Bismuth	Yellow.
Mercury, as persalt [574],	

	Colours of precipitates.
Ferridcyanide of potassium gives, with—	
Iron, as protoxide, a	*Blue.*
Copper, as black oxide, a	*Green.*
Cobalt, Manganese, Nickel, Silver	*Brown.*
Zinc, a	*Red.*
Ferrocyanide of potassium gives, with—	
Bismuth, Cerium, Columbium, as tantalic acid, Iron, as protosalt [537], Lead, Mercury [573 and 574], Silver, Tin, as protosalt, Yttrium, Zinc, Zirconium	*White.*
Niobium, a	*Yellow.*
Chromium, as chromic acid, Cobalt [482], Nickel, Vanadium, as vanadic acid,	*Green.*
Copper, as black oxide, Titanium	*Brown.*
Manganese [563]—free acids should not be present, a	*Pale red.*
Hydrochloric acid gives, with—	
Lead, Mercury, as subsalt, Silver [642],	*White.*
Hydrofluosilicic acid gives, with—	
Barium, a	*White.*
Hydrosulphuret of ammonia gives, with—	
Aluminum, Columbium, Mercury, as persalt, when agitated,† Zinc, unless the solution is very acid,	*White.*
Antimony,* as protosalt, Arsenic, the solution being acidified with hydrochloric acid [442], Cadmium, *Tin,** as persalt, from neutral and acid solutions,	*Yellow.*

† *The colour depends on the quantity of re-agent* [574].

	Colours of precipitates.
Hydrosulphuret of ammonia gives, with—	
Manganese, as protosalt, in alkaline solutions [563], a	*Flesh red.*
Gold,* in neutral and acid solutions,	*Brown.*
Molybdenum,* as molybdous oxide,	
Platinum,* in acid, and neutral solutions [602],	
Rhodium, as sesquisalt—after some time,	
Tin,* as protosalt [668],	
Vanadium,* as vanadic acid,	
Bismuth, in neutral, and acid solutions. If excess of nitric or hydrochloric acid is present, water must be added,	*Black.*
Cobalt, in neutral solutions [482],	
Copper*	
Iron—if as persalt, in neutral solutions [538],	
Lead	
Mercury, if as persalt, enough of the re-agent being added [574],	
Nickel, in neutral solutions [586],	
Osmium	
Palladium*	
Silver	
Vanadium,* as oxide,	
Iodide of potassium gives, with—	
Mercury,* as subsalt,	*Yellow.*
Silver	
Mercury,* as persalt, a	*Red.*
Palladium	*Black.*
Platinum,* as chloride,	
Iron, in the metallic state, gives, with—	
Titanium, as an alkaline titanate, a	*White.*†
Copper is precipitated from its salts, in the metallic state by iron.	
Nitrate of silver gives, with—	
Molybdenum, as molybdic acid [581], a	*White.*
Arsenic,* in neutral solutions,—just enough of the re-agent should be added [442],	*Yellow.*
Chromium, as chromic acid, a	*Red.*
Oxalate of ammonia gives, with—	
Calcium—free hydrochloric acid should not be present [468],	*White.*
Cerium	
Strontium	

† *It is first blue* or *violet*, but gradually changes.

	Colours of precipitates.
Oxalic acid gives, with—	
Calcium,* free hydrochloric acid should not be present [468],	*White.*
Strontium [655],—particularly in presence of ammonia,	
Gold, as terchloride [509], a	*Metallic.*
Perchloride of gold gives, with—	
Tin, as protosalt, if nitric acid is added, a	*Purple.*
Perchloride of mercury gives, with—	
Tin, as protosalt, the re-agent being in excess, a	*White.*
Phosphate of soda gives, with—	
Antimony, as protosalt,	*White.*
Glucinum	
Magnesium, in presence of ammonia [558], and the other alkaline earths having been precipitated,	
Manganese	
Mercury, as subsalt,	
Yttrium	
Cobalt, a	*Blue.*
Potash gives, with—	
Aluminum*	*White.*
Antimony,* as protosalt,	
Bismuth	
Cadmium	
Cerium [471],	
Glucinum*	
Iron, as protosalt—ammoniacal salts should not be present [537],	
Lanthanum	
Lead*	
Magnesium	
Manganese—sal-ammoniac should not be present [563],	
Tellurium,* as tellurous acid,	
Thorium	
Tin*	
Vanadium,* as oxide,	
Yttrium	
Zinc*	
Zirconium	
Mercury, as persalt. Enough potash must be added [574],	*Yellow.*
Platinum,* in a solution not too dilute, and free hydrochloric acid being present [602],	
Rhodium, as sesquisalt—after protracted digestion,	

	Colours of precipitates.
Potash gives, with—	
Cobalt, much sal-ammoniac not being present [482],	*Blue.*
Copper, as black oxide [497],	
Chromium,* as sesquioxide [476],	*Green.*
Nickel	
Uranium [682],	
Gold, as terchloride, and not a cold acid solution —after some time,	*Brown.*
Palladium*	
Silver—ammoniacal salts should not be present,	
Mercury, as subsalt,	*Black.*
Molybdenum, as molybdous oxide,	
Protochloride of tin gives, with—	
Mercury, a	*Gray.*
Gold, in concentrated solutions—a drop of nitric acid being added, a	*Purple red.*
Platinum, unless the quantity is too small [602], a	*Brown.*
Silver [642], a	*Metallic.*
Protonitrate of mercury gives, with—	
Chromium, as chromic acid, an	*Orange.*
Gold, as terchloride, a	*Black.*
Protosulphate of iron gives, with—	
Gold, as auric acid [509], a	*Brown.*
Silver, a	*Metallic.*
Sal-ammoniac gives, with—	
Vanadium, as vanadic acid, a	*White.*
Platinum,* in a solution not too dilute, and free hydrochloric acid being present [602], a	*Yellow.*
Molybdenum, as molybdic oxide, a	*Brown.*
Soda gives, with—	
Aluminum*	*White.*
Bismuth	
Lanthanum	
Tellurium, as tellurous acid,	
Thorium	
Uranium [682], a	*Greenish.*
Sulphate of copper gives, with—	
Arsenic, in neutral solutions, a	*Green.*
or a	*Greenish blue.*
Sulphate of potash gives, with—	
Barytes	*White.*
Calcium, in concentrated solutions [468],†	

† *Slowly, or not at all,* in very dilute solutions [468].

	Colours of precipitates.
Sulphate of potash gives, with—	
Lead	White.
Strontium, in concentrated solutions,	
Thorium, the re-agent being in excess, and the fluid concentrated [662], then cooled,	
Zirconium—enough of the re-agent must be present [699],	
Sulphite of ammonia gives, with—	
Tellurium, as tellurous acid [658], a	Black.
Titanium, as titanic acid, heat being applied, a	White.
Silver, a	Metallic.
Sulphocyanide of potassium gives, with—	
Columbium, as tantalic acid, a	White.
Niobium, a	Yellow.
Iron, as persalt, a *blood red* tint.	
Sulphuret of potassium gives, with—	
Cerium, a	White.
Sulphuretted hydrogen gives, with—	
Mercury, as persalt, the solution being agitated,†	White.
Zinc, in neutral solutions,	
Antimony,* as protosalt, in an acid solution,	Yellow.
Arsenic, the solution being acidified with hydrochloric acid,	
Cadmium—if free acid is present, water must be added,	
Chromium, as chromic acid, free acid being present,‡	
Iron, as persalt,‡	
Tin, as persalt, in neutral, and acid solutions,	
Manganese, in acid solutions [563], a	Flesh red.
Gold, in neutral and acid solutions,	Brown.
Iridium	
Molybdenum, as molybdic acid, the re-agent being in excess—after a while,	
Platinum, in neutral, and acid solutions,	
Rhodium, as sesquisalt—after some time,	
Tellurium	
Tin, as protosalt, in neutral, and acid solutions,	
Bismuth, in neutral, and acid solutions. If excess of nitric or hydrochloric acid is present, water must be added,	Black.
Copper, as black oxide,	

† The colour depends on the quantity of re-agent [574].

‡ The precipitates with chromium, and iron, are sulphur.

	Colours of precipitates.
Sulphuretted hydrogen gives, with—	
Iron, as protoxide, in alkaline solutions,	
Lead—if much mineral acid is present, water must be added,	
Mercury, as subsalt—if as persalt, the re-agent must be in sufficient quantity [574],	*Black.*
Nickel, in alkaline solutions [586],	
Osmium	
Palladium	
Silver	
Sulphuric acid gives, with—	
Barium	
Calcium—the solution should not be too dilute [468],	
Columbium, as tantalic dissolved in hydrochloric acid,	*White.*
Lead	
Strontium, in solutions not too dilute [655],	
Sulphurous acid gives, with—	
Osmium, a *yellow*, &c. [593], solution.	
Tellurium, as tellurous acid [658], a	*Black.*
Tartaric acid gives, with—	
Potassium, in neutral or alkaline, and not too dilute solutions [623]—the re-agent being in excess,	*White.*
Sodium, in highly-concentrated solutions [652],	
Tin, in the metallic state, gives, with—	
Molybdenum, as molybdic acid—free hydrochloric acid being present—a *blue*, then a *green*, and lastly, a *black* tint.	
Tincture of galls gives, with—	
Columbium, as tantalic dissolved in hydrochloric acid, a	*Yellow.*
Iron, as peroxide—sometimes a	*Violet.*
Osmium, a *purple* tint, &c. [593].	
Titanium, as titanic dissolved in hydrochloric acid, an	*Orange.*
Iron, as peroxide—sometimes a	*Black.*
Water gives, with—	
Antimony, as protochloride—tartaric acid not being present [437],	*White.*
Bismuth, as chloride,	
Tin, *as neutral* protosalt, a *milkiness.*	

Zinc, in the metallic state, gives, with—	Colours of precipitates.
Columbium, as tantalic acid—hydrochloric acid being added in excess,	*White.*
Silver	
Titanium, as an alkaline titanate, dissolved in hydrochloric acid,†	
Cadmium	*Gray.*
Tin, as persalt—free nitric acid not being present,	
Molybdenum, as molybdic acid—free hydrochloric acid being present—a *blue*, then *green*, and lastly *black* tint.	
Tungsten, as tungstic acid, a *blue* tint.	
Niobium, as niobic acid—free hydrochloric acid being present [589],	*Brown.*
Antimony [438],	*Black.*
Platinum [602],	
Ruthenium, as chloride [634], acidified with hydrochloric acid,	
Tellurium, as tellurous acid [658],	
Copper is precipitated on the surface of zinc, immersed in a fluid containing it.	

† The precipitate is first blue, or violet.

CHAPTER VI.

ORGANIC CHEMISTRY.

Organic Substances, 1.—Food of Plants, 3.—Digestion and Respiration of Plants, &c., 9.—Peculiarities of Organic Elements, and their Compounds, 20.—Oxalic Acid, 31.—Cyanogen, 37.—Compounds of Cyanogen, &c. Hydrocyanic or Prussic Acid, 42.—Urea, 54.—Uric Acid, 55.—Acetic Acid, 58.—Creosote, 67.—Formic Acid, 69.—Tartaric Acid, 73.—Racemic Acid, 80.—Citric Acid, 81.—Malic Acid, 85.—Tannic Acid, 89.—Manufacture of Leather, 95.—Gallic Acid, 97.

1. ORGANIC SUBSTANCES.—Organized are generally distinguished, without difficulty, from inorganized beings. Inorganic matter increases by external addition, atom being added to atom:—hence, the regular form of crystals, &c. Organized matter increases by interstitial deposition, and grows in all directions:—hence, its irregular forms. Inorganic matter is subject to the ordinary chemical laws: vitality causes these laws to be suspended. Inorganic bodies contain no principles of increase, repair of waste, or replacement; living beings suppose the processes of nutrition, and of reproduction. The difference between animals and plants is, also, generally very distinct. The transformation of nutriment into the living substance, or, as it is called, "assimilation," is the character of mere organic; "in-nervation," that of animal existence. Plants have not, like animals, the power of locomotion, sensation, or volition. They do not, like them, gradually renew their structure. Animals change, not only the soft parts of their bodies, but even, in a few years, their very bones. Inorganic matter is the nutriment of plants: organic matter, that of animals. Nevertheless, it must be admitted that the mineral, the vegetable, and the animal kingdoms, blend into each *other* so imperceptibly that, however we

may attempt to separate, or to mark the boundaries between them, it is scarcely possible to say where one terminates, and another begins. But our knowledge on this subject is much more clear at present than formerly.

2. Organized substances, are constituted of but few elements. Vegetables, consist principally of carbon, hydrogen, and oxygen; animal substances, of carbon, hydrogen, oxygen, and nitrogen. Some vegetable substances, however, do, and some animal substances do not contain nitrogen. It is always present, in the fluids which pervade the organs of plants: and is sometimes found in the roots—as, for instance, in those of *beet*; at others, in the stem—as in that of the *maple*; it is detected in all blossoms, and unripe fruits. Some organic substances contain carbon and hydrogen, but no oxygen; in others, the oxygen is more, or less, than is sufficient, along with the hydrogen, to form water. Organic matter sometimes affords, also, sulphur, phosphorus, chlorine, fluorine, iron, lime, magnesia, potassium, sodium, &c., in small quantities.

3. Food of Plants.—The organic matter of the mould, consisting of decayed vegetables, &c., is perpetually forming carbonic acid. This is intended to be absorbed by the plant: and, until such absorption takes place, it protects the organic matter from further decomposition—which would be merely a source of waste. Water (or its elements) is assimilated, along with carbonic acid:—it serves besides, as a vehicle for the food of plants. Charcoal and distilled—or rain—water will not, under ordinary circumstances, maintain plants in a thriving state: and they enable them, even to exist, only because of the salts contained in the charcoal, and of the ammonia which [inorg. chem. 260] it condenses. It is probable that carbon does not constitute the food of plants, except when it is in the nascent state.

4. Dr. Priestly asserted, and it is now no longer doubtful, that nitrogen is absorbed by plants:—indeed their value, as articles of food, is chiefly dependent on the quantity of that element which they contain. Some consider that the nitrogen is obtained directly from the atmosphere; others that it must previously assume the form of *ammonia*—by the nitrogen of the atmosphere uniting with

nascent hydrogen, evolved by decomposing organic substances. Some plants have more power to assimilate nitrogen, than others. Trefoil, planted in pure sand, in which it thrives almost as well as in ordinary soil, has, when fully grown, twenty-six per cent. more nitrogen than the seed which produced it. Wheat, in the same circumstances, does not come to maturity; and, in the end, contains less nitrogen than was in the seed.

5. Plants have not the power of rejecting poisonous substances—sulphate of copper, for example, or the water that drains from a heap of manure, and which is injurious, because overcharged with nutriment.

6. When the plant has reached such maturity that the organs, by which it obtains food from the atmosphere, are formed, it no longer requires, from the mould, carbonic acid or moisture—provided the water (or its elements) necessary to be assimilated along with the carbonic acid, is supplied by dew. Caoutchouc, and wax, often preserve, in plants that derive little or no nourishment from the soil, the moisture which they obtain from the atmosphere; as the skin which forms on milk, protects it from evaporation.

7. Plants are ascertained to resemble animals, in having excretions:—these occur through the roots. Buchner found that the charcoal which had been used by Lukas—in experiments, made, during several years, for the purpose of ascertaining its power of sustaining plants—contained a brown substance, soluble in alkalies: this was *excrement*. The excretion of one species of plant, may be, not only not injurious, but even salutary to others. Hence, one reason why rotation of crops is advantageous. Dr. Wollaston has shown that what are called "fairy rings," and are formed by dark luxuriant grass, arise from fungi that commence at a point, and grow in successive circles. The place they occupied is incapable of producing them a second time, although grass will flourish there—and the more abundantly, on account of the decomposed roots, and excrement, of the preceding crop of fungi. Plants which, from the nature of their excrements, are fond of growing near each other, are said to be "social." The acid excretions of plants, contribute to the disintegration of rocks.

8. When the plant has produced leaves, it plentifully

returns in the shape of excrement, the nourishment which when young, it obtained from the earth, as carbonic acid: and this excrement, when decomposed, affords carbonic acid to the next generation of plants. Gigantic ferns, &c. —at first the only produce of the earth—were enabled, on account of the great size of their leaves, to dispense with nourishment from the ground: and, therefore, instead of exhausting, they fertilized it. Fallowing, or a succession of water containing oxygen, causes the decomposition of excrement.

9. Digestion, and Respiration, of Plants, &c.—Light, acting on the back of the leaves, and other green parts of the plant, decomposes the carbonic acid, which is obtained either from the sap or the atmosphere, oxygen being evolved. This process is called the *digestion* of plants. It occurs, even with leaves separated from the plant: since, if they are placed in water containing carbonic acid, oxygen will be evolved, by the action of the sun's light. From this decomposition of carbonic acid, by vegetables, it may be easily conceived, how vast a quantity of oxygen is set free, in the hotter portions of the earth. The air, therefore, which passes from the tropics [pneum. 104] towards the polar regions, is not only a means of moderating the cold, but also, being extremely rich in oxygen, affords a proper supply of that most necessary element, to those parts of the earth in which, from the diminished intensity of the sun's light, it is obtained less abundantly, by the decomposition of carbonic acid, produced there by combustion, respiration, &c. And the days are longest, precisely at the time, during which the plant requires to decompose most carbonic acid. If an alkali is combined with carbonic acid, the latter can no longer be decomposed by leaves, &c. At night, oxygen is absorbed by plants, to form carbonic acid with the crude carbon contained in their sap. The evolution of carbonic acid, by plants, is termed their "respiration." It is probably continual: although, on the whole, the volume of carbonic acid being diminished, the quantity absorbed is greater than what is given out. The leaves, and other parts containing volatile oils which, by combining with oxygen, change into resin, absorb the most of that element.

Some plants, as the *cacalia ficoides*, are sour in the morning, acids having been formed by the absorption of oxygen; tasteless at noon; and bitter in the evening, from excess of hydrogen.

10. Fresh wood absorbs oxygen; dried wood, when moistened, changes oxygen into carbonic acid. Pure woody fibre consists of carbon, and the elements of water:—but wood generally contains a larger quantity of hydrogen, than would be sufficient, along with its oxygen, to form that fluid. The excess is supplied by the decomposition of water; and, therefore, more oxygen is evolved, than arises merely from the decomposition of carbonic acid. Those parts of the plant which are not green, expire carbonic acid—but never oxygen. The actinic principle [opt. 210], is highly important to the chemical changes which take place in plants. The green colour of plants depends, to a great extent, on the presence of light: and, without the latter, they are generally colourless. M. De Humboldt, however, found green plants growing in total darkness, at the bottom of one of the mines of Freybourg. Also, sea weeds, taken from the bottom of deep seas—and therefore, it is likely, produced in total darkness—are often highly coloured. Plants, grown in the absence of light, sometimes contain peculiar substances. The blanched shoots of the potato, formed in cellars, or beneath the soil, contain *solanine*, a poisonous principle, which disappears under the influence of light: its presence renders the unripe potato unwholesome. Light is found to impede the production of sugar, in certain circumstances. The blanched portions of celery, if exposed to light, would be bitter. The large leaves of beet, when it is intended for the manufacture of sugar, should be allowed to cover the ground: otherwise the amount of saccharine matter will be diminished.

11. Starch, from the elements of which it consists ($C_{12}H_6O_6+2HO$), may be considered as formed, directly by the union of water with the carbon of the decomposed carbonic acid: and may be looked upon as the first substance, elaborated by the plant. The external coatings of the grains of starch would, if deprived of water, become lignine ($C_{12}H_6O_6=C_{12}+8HO$): and thus cells would be

formed, the aggregate of which would constitute woody fibre. The change of starch into other substances, may be traced with equal facility—water, carbonic acid, &c., being given off. Starch is, to the tree, what fat is to the animal—a magazine, whence the supply of future demands is intended to be taken. With this difference, however, that the starch is a source of increase: while the fat merely supplies the carbon [inorg. chem. 177], and hydrogen, expended in producing vital heat, &c.

12. The minute portions of salts, present in the sap, perform very important functions, in the changes which occur. The alkalies are particularly necessary, since organic acids will not be generated, unless they are present. One of the greatest advantages of fallowing, arises from the action of the atmosphere producing further disintegration of the elements of the soil, and thus rendering a fresh quantity of alkali soluble. All ashes obtained from plants, contain carbonates derived from the organic acids, which were united with bases in the plant. In different circumstances, plants of the same species may contain different oxides: but the total amount of atoms, depends on the number of atoms of organic acids. That is, the amount of oxygen, in the sum of the bases, will always be the same:—for, the amount of oxygen in the bases, and their saturating power [inorg. chem. 31], always correspond. Liebig has shown, that the total amount of bases, in a plant, never varies—the excess of one always making up, precisely, for the deficiency of another. Iron, and manganese, are found in the bark of plants: but never as the constituent of an organ.

13. Fluids are exhaled from the leaves of plants, and principally from their surface:—in herbaceous plants, however, absorption is equal in both surfaces. When the soil is unfavourable, the absorption [6 and 8] is very great:—an analogous means has, sometimes, been applied to the nourishment of the human body. Exhalation from the stomata—or openings, on the surface of the leaves—occurs only when natural, or artificial, light is present. The leaves, though not primarily intended for that purpose, absorb water. Their fall, seems to arise from the suspension of vegetation, and interruption of the course of the

sap; or from the silex, which is deposited by the sap, and which, when once precipitated, is never again taken up.

14. Plants which have the largest leaves, are the least injurious to the ground:—they do not exhaust it so much as others, on account of deriving a large portion of their nourishment, from the atmosphere. Hence, one reason why green crops are more beneficial than grain crops. Crops usually considered as exhausting, under proper treatment may not be so. Thus, if all the constituents of the flax, except the fibre, are returned to the soil, it does not exhaust it: as the fibre affords little or no ashes, it takes almost nothing from the soil. Trees that annually shed their leaves, require a greater amount of alkali, in the soil, than pines, &c.

15. The sap ascends through the alburnum, and wood: and the more abundantly, the nearer to the medullary tube—or middle of the trunk. When it reaches the leaves, it is freed from atmospheric air, &c., and gives off its superfluous water, by *transpiration*. Nearly two-thirds of the sap exhale through the stomata; and a sun-flower was found, by Hales, to lose by such evaporation, seventeen times more moisture than an equal surface of the human body, by insensible perspiration. Sap has been known to rise in a tube [hyd. 107], to a height equivalent to forty-three feet of water pressure. The roots, and leaves, of plants absorb various fluids; these are partially returned to the atmosphere, by what is called *expiration*.

16. Like animals, plants require air:—the smallest seed, or the egg of the most minute insect, becomes unproductive *in vacuo*. The richest mould will not secure a plant from death, if atmospheric air is not allowed access to it. The free admission of air to the soil, and to the roots of plants, is one of the advantages of ploughing, &c. And, so well were even the ancients acquainted with the utility of turning up the soil, that, when Cato was asked what was necessary for proper tillage, he answered—"first, to plough well; second, to plough well; third, to manure." Nearly all the gases, except atmospheric air, are injurious, or even fatal, to plants:—but cyanogen, is the most destructive of all.

17. A certain amount of heat is necessary, both for ani-

mals, and plants; and has, therefore, by various m
been secured to them. The excess of animal heat is
ried off, by perspiration; and its diminution is supp
by internal organization [inorg. chem. 172]. The in
fect conducting power of the earth, preserves an eq
temperature to the roots of plants. It is so bad a
ductor of heat, that at a hundred feet under its su
the mean temperature—in England, 52°, and in Cair
—is always maintained.

18. Fruit, until it is ripe, or nearly so, produce
same change on the atmosphere, as the leaves [9].
mode in which it ripens, may be exemplified by the
This is at first tasteless, consisting of loose woody
containing starch, ($C_{12}H_9O_9+2HO$.) The latter, b
sorbing oxygen from the atmosphere, becomes ta
acid ($C_8H_4O_{10}$), four atoms of carbonic acid, and
atoms of water, being disengaged. ($C_{12}H_9O_9+2H$
$O_{14}=C_8H_4O_{10}+4CO_2+7HO$. The tartaric forms
acid ($C_8H_4O_8$):—and, if this occurs during the time,
gen is given off by the plant, two atoms of oxygen a
free; but if, during the time carbonic acid is evolve
atoms of tartaric acid form five atoms of malic acid,
atoms of carbonic acid, and four atoms of water.
former case, $C_8H_4O_{10}=C_8H_4O_8+O_2$: and, in the
$6C_8H_4O_{10}=5C_8H_4O_8+8CO_2+4HO$. Sugar ($C_{12}H_{11}$
produced by starch, or lignine, combining with th
ments of water.

19. Air is necessary to the seed, since, while it i
minating, oxygen is required to form sugar—carboni
and, no doubt caloric being evolved. Moisture, al
indispensable, and a certain amount of heat. But,
it is in the ground, light must be entirely, or almo
tirely, excluded from it. Vast quantities of nutrime
absorbed by the seed—the great effort of nature app
to be, its production by the plant. Hence, another
why green crops exhaust the earth, less than grain

20. PECULIARITIES OF ORGANIC ELEMENTS, THEIR COMPOUNDS.—They are, almost always, mor
plicated than those which belong to inorganic chem
—like the latter, they enter into combination with
other, and with the more simple substances. They

acids, and bases, with oxygen, and sulphur; and some of them, hydracids, with hydrogen. In which case, as with the inorganic acids, their hydrogen is evolved [inorg. chem. 25]; or, combining with the oxygen of an oxide, it forms water.

21. Organic elements, often consist of certain *radicals* united with other substances. Some of these radicals are known; the existence of others, is inferred with great probability; and there are others, no doubt, which, as yet, are altogether unknown. The doctrine of compound radicals has, already, very much simplified our chemical knowledge; and, when more fully developed, will lead to its still further advancement. Should the same group of elements be found in a number of compounds, which are produced merely by the change, or interchange, of other elements more weakly united than those of the group, it is very reasonable to consider that group, as itself an element. This may be extremely well illustrated, by oil of bitter almonds ($C_{14}H_6O_2$). If the latter is supposed to consist of a radical $C_{14}H_5O_2$ (which has been termed *Benzyle; symb.* Bz), united with an atom of hydrogen, a number of compounds, intimately connected with each other, will be obtained, by merely changing the atom of hydrogen, for oxygen, chlorine, &c. Thus Benzoic acid ($C_{14}H_5O_3 = C_{14}H_5O_2 + O$), will be formed from hydruret of benzyle (oil of bitter almonds), by replacing the atom of hydrogen with an atom of oxygen, &c. The justness of such a view is confirmed by the fact, that oil of bitter almonds may, with little difficulty, be reproduced from the new combinations. We have already mentioned [inorg. chem. 310] that certain compounds, belonging to inorganic chemistry, are supposed to have a compound radical.

22. In some instances, a portion of the radical itself, is replaced. Thus, $C_4H_6O_2$ constitutes alcohol; $C_4H_6S_2$, mercaptan. The sulphur, and oxygen compounds are, in such a case, analogous. If the hydrogen of acetyle (C_4H_3) is replaced by chlorine, acechloryle (C_4Cl_3), a new radical, is obtained. The combinations of such corresponding radicals, also, give rise to analogous compounds; and, if they are broken up, by means of affinities still stronger than those which *hold them* together, they will produce corres-

ponding results. Thus $C_4H_3O_3+HO$ (hydrated acetic acid), heated with potash, will give $2CO_2+C_2HH_3(2CO_2+2CH_2)$; and $C_4Cl_3O_3+HO$ (chloroacetic acid), decomposed, in the same way, will give $2CO_2+C_2HCl_3$.* A portion of the elements constituting the compound radical may, in the formation of a new radical, be removed. Thus the hypothetical ethyle (C_4H_5), deprived of two atoms of hydrogen, becomes acetyle (C_4H_3).

23. When an organic substance is acted upon, by dry chlorine, the latter sometimes replaces more or less of the hydrogen belonging to the body: at others, it removes hydrogen, and forms with it free hydrochloric acid. When water is present, along with the chlorine, its hydrogen goes to the chlorine, and its oxygen to the organic substance. Generally speaking, however, some of the chlorine combines with the oxygen; and, in the form of hypochlorous, or chlorous acid, unites with the organic substance.

24. Nitric acid, in some instances, merely gives oxygen to the organic body; but, most frequently, the oxygen, at the same time, replaces some of its hydrogen. The nitrogen, nitrous oxide, or nitric oxide, of the nitric acid may, also, enter into combination.

25. When chlorine, or oxygen, takes the place of hydrogen, new radicals—which are sometimes more simple—will be produced. Thus, if to aldehyd (C_4H_3O+HO), six atoms of chlorine are added, the result will be chloral (C_4Cl_3O+HO), and three atoms hydrochloric acid. But, if five atoms of the hydrogen of alcohol ($C_4H_6O_2$), are replaced by oxygen, the result will be two atoms of oxalic acid ($2C_2O_3$) and six atoms of water. When the organic compound does not contain nitrogen, it is changed, by oxygen, into the oxides of more simple radicals. Thus, alcohol ($C_4H_6O_2$) and two atoms of oxygen, become aldehyd (C_4H_3O+HO) or hydrated oxide of *acetyle* and two atoms of water. Oxalic acid (C_2O_3) and oxygen, become two atoms carbonic acid ($2CO_2$).

Substances, which belong to the same class, form compounds, that bear the same relation to each other, as exists between themselves. Thus, wine alcohol ($C_4H_6O_2$), gives acetic acid ($C_4H_3O_3$); methylic, or wood alcohol ($C_2H_4O_2$;

* Chloroform.

formic acid (C_2HO_3); oil of potato spirit ($C_{10}H_{12}O_2$) or amylic alcohol, valerianic acid ($C_{10}H_9O_3$); and ethal ($C_{32}H_{34}O_2$), ceytillic acid ($C_{32}H_{31}O_3$). Each acid has one atom more oxygen, and three atoms less hydrogen, than the corresponding alcohol.

26. Sulphuric acid acts sometimes, catalytically [inorg. chem. 135]; at others, it combines, unchanged, with the organic body. If it is decomposed, an atom of its oxygen, along with an atom of the hydrogen of the organic body, form water; and the resulting sulphurous, along with an atom of undecomposed sulphuric acid, enters into combination, as hyposulphuric acid.

27. When an organic body is fused with potash, it is broken up into simpler compounds; or, it is oxidated, water being decomposed, and hydrogen evolved. At high temperatures, carbonic acid is always produced.

28. If the organic body contains nitrogen, when it is decomposed by strong acids, by being boiled with caustic potash—or fused with its hydrate—water is generally decomposed, and ammonia formed. If the decomposition is effected by potash, ammonia is disengaged, and oxide of the new radical combines with the potash. Should the substance be very rich in nitrogen, some of the latter may, along with oxygen, form cyanic acid (C_2NO), which will combine, with the potash, and produce a compound that, by dissolving in water, is changed into carbonate of ammonia, and carbonate of potash. $(C_2NO+KO)+4HO=(CO_2+NH_4O)+(CO_2+KO)$.

29. Organic combinations, subjected to destructive distillation, are decomposed into more simple compounds—carbon being, sometimes, deposited. The nature of the results will, however, be modified by the temperature employed. During the first period of the distillation, organic acids of the more simple radicals, carbonic acid, water, and combustible fluids—miscible with water—are produced. In the second period, the compounds, formed during the first, are decomposed; the oxygen of the acids unites with part of their hydrogen and carbon, forming water, carbonic oxide, carbonic acid, &c. A portion of the carbon is, generally, deposited: and another portion, uniting with hydrogen, forms fixed, or volatile, oleaginous substances.

The products of the last period are almost always carbonic oxide, olefiant gas, and light carburetted hydrogen. If certain bases are present, they will be found, afterwards, in combination with carbonic acid.

30. Organic bodies, containing nitrogen, when subjected to destructive distillation, produce ammonia—and, sometimes, cyanic acid; but, ultimately, cyanogen, and hydrocyanic acid.

We now proceed to examine the most important organic substances. They are not easily classified. We will therefore place them in the order which suggests itself, as either the most natural, or, under the circumstances, the most convenient.

31. Oxalic* Acid:—*symb.* C_2O_3, or $\overline{O}$; *equiv.* 36. It was discovered by Scheele, in 1776. It is found in the sorrel, and many other plants:—also, combined with lime, in concretions of the human body; and, with oxide of iron, in a mineral substance. It may be formed, with great facility, from all organic compounds which do not contain nitrogen, by oxidizing their elements with nitric acid. If nitrogen were present, ammonia would be produced at the same time. Berthollett procured half its weight of oxalic acid from wool, by heating it with nitric acid. It is conveniently obtained, by digesting, with a gentle heat, one part sugar—or, what is better, potato starch—and five parts nitric acid, specific gravity 1·42, diluted with ten parts water. Four-fifths of the dilute nitric acid are to be added at first, and the remaining fifth, when the action has become moderate. The sugar would be changed into oxalic acid, by removing the hydrogen, and replacing it with oxygen. $C_{12}H_{11}O_{11}+O_{18}=6C_2O_3+11HO$. But, as saccharic acid, and other substances are formed, along with the oxalic acid, the process is somewhat more complicated. When gaseous products are no longer evolved, the liquid is to be evaporated. This will cause the oxalic acid to separate as colourless transparent crystals—which, if the crystallization is rapid, are in the form of small irregular needles. They must be purified, by solution, recrystallization, and drying with bibulous paper, or porous earthenware. On being heated, they give off their two atoms

* *Oxalis*, sorrel. Lat.

water of crystallization, and the hydrate, containing a single atom, remains in the form of a white powder.

32. Oxalic acid is without odour, but its taste is strongly acid, even when dissolved in a considerable quantity of water;—its solution in 30,000 times its weight of that fluid, will redden litmus paper. When heated in a retort, it is decomposed at 310° into formic acid (C_2HO_3), carbonic acid, and carbonic oxide, without any residue. If heated rapidly in open vessels, part of the acid is decomposed: and another part sublimes, unchanged—the fumes being irritating, and producing a cough. Heated with strong sulphuric acid, it is decomposed, as we have already described [inorg. chem. 263]. Heated with peroxide of manganese, it is changed into carbonic acid, one atom of which combines with the resulting protoxide. $MnO_2+C_2O_3=(CO_2+MnO)+CO_2$. It is doubtful whether it should be considered as belonging to organic, or inorganic chemistry.

Binoxalate of potash $[(C_2O_3+KO)+(C_2O_3+HO)+2Aq]$—sold under the name of "essential salt of lemons"—is used for removing iron moulds, and other metallic stains, from linen.

33. Oxalic acid is a violent poison. It has been, sometimes, mistaken for Epsom salts (SO_2+MgO). But the sour taste of the acid, and the bitter taste of the salt, should be quite sufficient to distinguish them. Carbonate of lime (chalk), or of magnesia, is the antidote for oxalic acid, since the oxalate of lime, being insoluble, is inert: the carbonate should be administered after, if possible, the poison has been expelled, by an emetic.

34. All the oxalates [27] are decomposed at a red heat, the oxalic acid being resolved into carbonic acid, and carbonic oxide: of which the former combines with the base, if it is an alkali or an alkaline earth. When the base is metallic, if the metal is easily reduced, it is left in the metallic state; if not, as an oxide.

35. *Tests for Oxalic Acid.*—Oxalic acid may be known, by giving with lime water, and solutions of the soluble salts of lime, even when very much diluted, a white oxalate, soluble in nitric, and in hydrochloric acid. It gives, with chloride of barium, a white oxalate, insoluble in nitric, or hydrochloric acid. With nitrate of silver, a

white oxalate, which dissolves in nitric acid, and in ammonia.

36. Carbonic oxide [inorg. chem. 263] is supposed to be the radical of this acid, and to form compounds with various elements. Thus—

With oxygen, oxalic acid, ...	$2CO+O$
With hydrogen, mellitic acid, . . .	$4CO+H$
And croconic acid, ...	$5CO+H$
With chlorine, chloro-carbonic acid, . .	$CO+Cl$
With the radical of ammonia, oxamide, .	$2CO+NH_2$
With potassium, oxycarburet of potassium,	$7CO+3K$
With water, rhodezonic acid, ...	$7CO+3HO$

37. CYANOGEN:*—*symb.* C_2N, or Cy; *equiv.* 26·02. This substance, which is one of the compound radicals, was discovered by Gay Lussac. It does not exist ready formed in nature; but is very easily generated from bitter almonds, the kernels of peaches, plums, &c. It is produced, synthetically, in a variety of ways. When nitrogen is passed over a mixture of potash and charcoal, ignited together in a tube, cyanide of potassium (CyK) is formed, and carbonic oxide is evolved. $3C+KO+N=(C_2N+K)+CO$. It is very conveniently procured, by saturating a moderately dilute solution of prussic acid, with peroxide of mercury, evaporating the resulting solution of percyanide ($CyHg$) to dryness, and heating it in a green glass retort:—the mercury is reduced to the metallic state, and cyanogen is evolved.

38. Cyanogen is a colourless gas, of a penetrating odour, and irritating to the eyes. Its specific gravity is 1·819:—100 cubic inches weigh 56·4103 grains. It burns with a rose-coloured flame. It is condensed into a colourless liquid, at a pressure of about four atmospheres. Water, at 60°, absorbs 4·5 volumes, and alcohol, 23 volumes of this gas. The aqueous solution reddens litmus paper—on account of acids, produced by the decomposition both of water, and of the cyanogen.

39. It forms, with oxygen, cyanic acid (CyO; 34·02), which is monobasic, and is obtained only as a hydrate: fulminic acid (Cy_2O_2; 68·64), which is bibasic; and cyanuric acid (Cy_3O_3; 102·06), which is tribasic. With hydrogen, hydrocyanic (CyH; 27·02) or prussic acid. With

* *Cuanos*, azure; and *gennao*, I produce, *Gr.*; because the chief constituent of Prussian blue.

chlorine, chloride of cyanogen ($CyCl$; 61·49); and *solid* chloride of cyanogen (Cy_3Cl_3; 184·47). With iodine, iodide of cyanogen (CyI; 152·87). With bromine, bromide of cyanogen ($CyBr$; 105·99), &c.

40. Cyanogen combines with the various metals. Cyanides of the bases of alkalies, and of alkaline earths, are soluble: and are decomposed by acids—including the carbonic. But they are not decomposed, by ignition, if atmospheric air is excluded. Most cyanides of the heavy metals are insoluble: many of them are not decomposed by dilute oxacids, nor by strong nitric acid—except with difficulty: but nearly all of them, easily, and perfectly, by hydrochloric, and hydrosulphuric acids. All are decomposed, by ignition, into cyanogen and a metal, if they are cyanides of the noble metals: but if not, into nitrogen and carburets.

41. The cyanides of the heavy metals, though insoluble, combine with the soluble alkaline cyanides. Thus, cyanide of gold, is dissolved by cyanide of potassium. The insoluble cyanide is precipitated, from such a combination, by an acid—the soluble cyanide being decomposed. If any of these double cyanides, in solution, is mixed with the solution of a salt of a heavy metal, a new double cyanide is produced—the alkaline being replaced by its equivalent of the heavy metal.

42. Compounds of Cyanogen, &c.—Hydrocyanic or Prussic* Acid:—*symb.* C_2NH, or CyH; *equiv.* 27·02. It was discovered, by Scheele: and was carefully examined, by Gay Lussac. It is a constituent of the water distilled from the leaves, and blossoms of several stone fruits, &c.: and is produced by them in such quantity, that instances are on record of persons having been poisoned by liqueurs manufactured from them. For the same reason, an incautious use of bay-leaf, in cookery, has been attended with fatal results. It is a product of the destructive distillation of many substances, containing nitrogen.

43. *Anhydrous Hydrocyanic Acid* may be obtained in a variety of ways:—but, very economically, by distilling, at a gentle heat, a mixture containing three parts yellow prussiate of potash ($FeCy_3+2K$) in fine powder, two parts oil of vitriol, and two parts water: and conveying

* *Because first* obtained from Prussian blue.

the product into a well-cooled receiver, containing five parts fused chloride of calcium, in tolerably large pieces. The results are hydrocyanic acid, Everet's salt ($2\,FeCy+KCy$), and bisulphate of potash. $2(FeCy_3+2K)+6(SO_3+HO)=3CyH+(2FeCy+KCy)+3[(SO_3+KO)+(SO_3+HO)]$. The former salt, is yellow: but, by absorbing oxygen, and abandoning its cyanide of potassium, it becomes greenish, and then blue—being changed into *basic* ($3FeCy+2Fe_2Cy_3+Fe_2O_3$) Prussian blue. $9(2FeCy+KCy+O_3=2(3FeCy+2Fe_2Cy_3+Fe_2O_3)+9KCy$. When the chloride of calcium is covered with the fluid, it is poured off into a well-stopped bottle.

44. Anhydrous prussic acid is a colourless liquid. Its odour resembles that of peach blossom—which arises from its presence. Its specific gravity, at 77°, is 0·6969. It congeals into a fibrous mass, at 5°: when absolutely anhydrous, it is said not to congeal till—64°. It boils at 80°, which it should be remembered, is sometimes the temperature of the atmosphere, in summer. If not quite anhydrous, it volatilizes so rapidly in the air, as to become solid. It is highly combustible—burning with a white flame. Concentrated mineral acids, change it into formic acid (C_2HO_3), and ammonia—water being decomposed. $(C_2N+H)+3HO=C_2HO_3+NH_3$. Light decomposes it into ammonia, and a brown substance—the constitution of which is not known with certainty: but the decomposition is prevented, by small quantities of mineral acids.

45. It is a most violent poison. When pure, if a rod is dipped in it, and applied to the tongue of an animal, death ensues before the rod can be withdrawn. According to Liebig, its action on the blood is far more powerful than on the stomach. A cat will swallow two or three drops of anhydrous acid, diluted with about six ounces of water, without being at all affected. And two drops may be placed on her tongue without any injury, as long as she is not allowed to breathe:—but she dies, the very instant she respires. Ammonia, and chlorine, are antidotes for prussic acid; but, being themselves very deleterious substances, they must be used [inorg. chem. 246 and 329] with great caution. When the acid is at all strong, death occurs so rapidly, that no antidote can be administered, in sufficient time.

46. *Hydrous Hydrocyanic Acid*, may be obtained by distilling, from a bath of chloride of calcium, four parts crystallized ferrocyanide of potassium, two parts oil of vitriol, and eighteen parts water. The condensing apparatus ought to be of glass: and the vapours should be received into a vessel, containing twenty parts water—the process being stopped, when they have become thirty-eight parts.

47. Allowing for its being diluted with water, it is similar, in its properties, to the anhydrous. Its taste is bitter, and acid. It is liable to spontaneous decomposition: and the more so, in proportion as it is weaker. Hence, it is impossible to keep it at a given degree of strength. From this cause, it has frequently happened that, while the last portion of one bottle of the acid might, without any inconvenience, be administered to a patient in certain doses; the same amount of a new portion, nominally of the same strength, would produce very dangerous effects. The strength of a given acid may be ascertained, by the quantity of cyanide of silver, precipitated by means of nitrate of silver, from a certain quantity of it. The experiment must be made with the greatest care, and a very delicate balance must be used. The cyanide of silver should be dried, at a moderate temperature, and weighed. One hundred grains of an acid containing three per cent. of the anhydrous, should give 11·98 grains of cyanide.

48. *Tests for Cyanogen.*—Hydrocyanic acid, and the cyanides, in solution, are known by giving, with nitrate of silver, a white precipitate ($AgCy$). The latter, is soluble in cyanide of potassium: it emits, when moistened with hydrochloric acid, the characteristic odour of hydrocyanic acid; and, when acted upon by heat, it leaves metallic silver, as residue. They give, with acetate of lead, a white precipitate ($PbCy$). With protosulphate of iron—which, from exposure to the air, has part of its iron peroxidated—a blue precipitate ($3FeCy + 2Fe_2Cy_3 = 3FeCy_3 + 2Fe_2$), provided potash is present. It is evident there must be, both protoxide and peroxide, that the cyanide, and sesquicyanide may be formed, by their decomposition:—potash is required, on account of the prussic acid not being able, by itself, to decompose the sulphate. The precipitate will be of a *dirty green* colour, until the excess of oxides of

iron, thrown down by the potash, is dissolved by adding hydrochloric acid: after which—according to the quantity of hydrocyanic acid present—there will be either a fine blue precipitate (Prussian blue), or a blue liquor. Sulphate of copper gives, when potash and hydrochloric acid are added, in the same way, and for similar reasons, a white precipitate. If some of a liquid, containing free hydrocyanic acid, is placed in a watch-glass: and another watch-glass, in which is a drop of hydrosulphuret of ammonia—with excess of sulphur [inorg. chem. 253]—is inverted over it for a few minutes, sulphocyanide of ammonia (CyS_2+NH_4) will be formed, on gently evaporating the drop of hydrosulphuret to dryness; and, on adding it to the solution of a persalt of iron, a beautiful blood red colour—due to the presence of persulphocyanide of iron (Fe_2+3CyS_2)—will be produced. The warmth of the hand may be used to accelerate the rising of the hydrocyanic vapour, from the lower watch-glass. This test is due to Liebig: and is sufficiently delicate, to detect the 473rd of a grain of prussic acid, in ten drops of liquid. The most decided test for prussic acid, is its dissolving peroxide of mercury—even though potash in excess is present.

49. Insoluble compounds, containing cyanogen, may be known, by heating them with a little potash and sulphur: then adding the solution of a persalt of iron. The blood red sulphocyanide will be formed.

50. FERROCYANOGEN, &c., AND THEIR COMPOUNDS.—Cyanogen, by combining with different metals [40], produces new radicals. With iron it forms *ferrocyanogen* ($FeCy_3$, or Cfy; 106·06)—which is known, in combination with hydrogen, as hydroferrocyanic acid ($FeCy_3+H_2$, or $Cfy+H_2$; 108·06) or *ferrocyanide of hydrogen*, a bibasic acid. It is capable of having its two atoms of hydrogen replaced by the same, or different metals. Thus, when they are replaced by potassium, ferrocyanide of potassium ($Cfy+2K$) or "yellow prussiate of potash," is the result. If a solution of this salt is mixed with a concentrated solution of a salt of iron, calcium, manganese, &c., each atom of the potassium is exchanged for an atom of iron, calcium, manganese, &c.: ferrocyanides of these metals being produced. Cyanogen is supposed, also, to form the radical

ferridcyanogen (Fe_3Cy_6=C*fy*$_2$, or C*fdy*; 212·12)—isomeric with ferrocyanogen, but having a double atomic weight. It is found, in combination with hydrogen, as hydroferridcyanic acid ($Fe_3Cy_6+H_3$; 215·12) or *ferridcyanide of hydrogen*, a tribasic acid, which is capable of having its three atoms of hydrogen replaced, also, by the same, or different metals. Thus, when they are replaced by potassium, the result is ferridcyanide of potassium (Fe_3Cy_6+3K) or red prussiate of potash. Other modes of expressing the composition of the complicated cyanides have been proposed; but the above seems natural, and sufficiently simple. Cyanogen forms, with platinum, platinocyanides; with cobalt, cobalticyanides, &c. With sulphur, sulphocyanides.

51. *Ferrocyanide of potassium* or yellow prussiate of potash (C*fy*+2K). That of commerce is sufficiently pure. When this salt is fused with carbonate of potash [inorg. chem. 622], the result contains also a cyanate—which, however, does not affect it, as a re-agent. $2(FeCy_3+2K)+(CO_2+KO)=2Fe+5CyK+(CyO+KO)+CO_2$. The cyanate, on adding water, is [28] immediately decomposed.

52. *Ferridcyanide of potassium* or red prussiate of potash (C*fdy*+3K), may be obtained by dissolving one part ferrocyanide of potassium of commerce in ten parts water, and transmitting chlorine through the liquid, until it is no longer capable of giving a blue tint to a drop of the solution of perchloride of iron. It is then to be concentrated by evaporation, and carbonate of potash is to be added, until there is a slight alkaline reaction. After which, having been filtered, and allowed to cool, beautiful red crystals of the salts will separate.

53. *Sulphocyanide of potassium* (C*y*S$_2$+K), may be obtained by mixing—extremely well—forty-six parts of anhydrous [52] ferrocyanide of potassium, with seventeen parts carbonate of potash, and thirty-two parts sulphur: then fusing the mixture in an iron pan with a cover, at a gentle heat, until the whole is clear and calm. The hyposulphite of potash that has been formed, is then decomposed, by increasing the heat to faint redness. After which the mass, having been half cooled, is crushed in pieces, and boiled *with alcohol*. Part of the salt will separate in

colourless crystals, on cooling the resulting solution: and the remainder may be had, by distilling off the alcohol.

54. Urea:—$C_2N_2H_4O_2$; *equiv.* 60·04. When cyanic acid is placed in contact with dry ammonia, a woolly mass (supposed to be $CyO+2NH_3+HO$) is the result. If this is heated, it evolves ammonia, and the residue is *urea*, a very important constituent of urine—being sometimes secreted, by a single individual, to so large an amount as 500 grains in twenty-four hours.

Urea may be obtained from urine:—but, more conveniently, by mixing, in powder, twenty-eight parts dry ferrocyanide of potassium, with fourteen parts peroxide of manganese, and calcining at a low red heat. When the mass has ceased to glow, it must be allowed to cool; after which the cyanate of potash, which has been formed, is to be dissolved out, fully, with cold water; and the solution is to be mixed with 20·5 parts sulphate of ammonia. The latter, at first, throws down some sulphate of potash:—but careful evaporation to dryness, causes the formation of urea, which, being dissolved out by boiling with alcohol, will separate from the alcoholic solution, on cooling. Urea is in the form of colourless four-sided prisms, that are very soluble in water. It fuses at 250°; but a high heat decomposes it—ammonia, cyanic, and cyanuric acids, being formed. It is isomeric with cyanate of ammonia (C_2NO+NH_4O); but it is not considered identical with it.

55. Uric Acid, $C_{10}H_4O_6N_4$; *equiv.* 168·08. It was discovered by Scheele, and is found in the urine of all carnivorous animals, of birds, reptiles, and of many insects. In combination with urea, it is deposited from human urine, on cooling, as a brownish, or yellow powder. The urine of serpents, or of birds, and guano—the decomposed excrement of aquatic birds—consists almost entirely of urate of ammonia. The stone-like concretions, in the joints of gouty persons, contain urate of soda—or of ammonia: and uric acid, is the basis of most calcareous deposits in the human bladder. It may be obtained, by boiling pulverized urinary calculi, or the excrements of the larger kinds of serpents, with caustic potash: and precipitating the resulting urate of potash, with hydrochloric acid in excess. Uric acid will be thrown down, in the form of

brilliant, white, silky-looking scales: which are to be boiled in water, washed, and dried.

56. Uric acid has neither colour, taste, nor smell. It is slightly soluble, in boiling water. It dissolves in sulphuric acid—from which, however, the addition of water precipitates it. When it is digested with nitric acid, carbonic acid, and nitrogen are evolved; and, if the solution, which contains ammonia, with a number of other substances, is evaporated to dryness, and ammonia, in excess, is added to the residue, a beautiful purple red colour will be produced. When uric acid is fused with hydrate of potash, carbonic acid, cyanate of potash, and cyanide of potassium are the results. Uric acid is decomposed, by heat, into urea, hydrocyanic acid, carbonate of ammonia, &c.

57. Uric acid is supposed to be derived from a radical termed *uryle* (C_2O_2+Cy)—or cyanoxalic acid. It consists of an atom of oxalic acid, having one atom of oxygen replaced by cyanogen; or, in other words, it is a combination of carbonic oxide—the radical [36] of oxalic acid—and cyanogen. It would enable us to express, very simply, the constitution of a number of compounds. Thus uric acid would be two equivalents of uryle, combined with one equivalent of urea [54], &c.

58. Acetic* Acid: *symb.* $C_4H_3O_3$, or $\overline{A}$; *equiv.* 51. As *vinegar*,† acetic acid has been known from the earliest times: but, was first obtained, as hydrated acid, by Löwitz, in 1793. It is derived from various sources. All liquids capable of the *vinous* fermentation—that is, of having alcohol produced in them—may change their alcohol, by oxidation, into acetic acid. Pure alcohol, however dilute, does not, by exposure to the air, become acid: but, mixed with yeast, it becomes acetic acid, by absorbing oxygen. $(C_4H_3O_3+HO)+O_2=(C_4H_3O_3+HO)+2HO$ or aldehyd plus two atoms water. Then $(C_4H_3O_3+HO)+O_2=C_4H_3O_3+HO$ or hydrated acetic acid. When fermentation is carried on at a low temperature, as in the manufacture of *Bavarian* beer, the liquid loses the power of becoming acid, even at a higher temperature: on account of the *fermenting matters* employed, having been altered into insoluble substances, and removed.

* *Acētum*, vinegar. *Lat.* † *Vin aigre*, sour wine. Fr.

59. *Vinegar* may be obtained, by adding to an infusion of malt, which has previously undergone the vinous fermentation, a little sour dough, or some other "ferment." It is manufactured, in wine countries, by mixing inferior wines that have become sour, with a little vinegar, and exposing them to the air, in casks partly filled with the husks of grapes. The addition of brandy, during the process, causes the vinegar to be of a proper strength.

60. In the manufacture of vinegar, free access of air is of deep importance. Spongy platinum will become red hot, in a mixture containing vapour of alcohol and common air: so rapidly will acetic acid be formed. Hence, the time required for manufacturing vinegar, is greatly shortened, by exposing a large surface of fluid to the atmosphere, and thus facilitating the oxidation of the alcohol. The liquor, therefore, which is intended to be acetified, is, in the improved process—after being warmed to between 75° and 83°—made to trickle through a mass of shavings steeped in vinegar; and the action of the atmosphere, soon causes the temperature to rise as high as 100°, or even 104°. After the liquid has passed three or four times, through the shavings, the operation is complete. During manufacture, three atoms of hydrogen are taken from the alcohol, and one atom of oxygen is absorbed. When atmospheric air is not supplied in sufficient quantity, it merely abstracts two atoms of hydrogen from the alcohol, and forms *aldehyd* ($C_4H_4O_2$) or *hypoacetous acid:* which, being volatile, flies off before it has combined with the two atoms of oxygen, required to change it into hydrated acetic acid: and thus waste is produced.

Alcohol cannot be acetified, if any essential oil, or pyroligneous acid is present.

61. *Pyroligneous* Acid.*—If wood is subjected to destructive distillation, a vinegar is obtained, which is charged with tar: but it is freed from the latter, by rectification, and neutralization with soda. Since it does not, like that obtained from wine, beer, &c., contain acetic ether, and is even contaminated by *creosote*, and other substances—produced by destructive distillation of wood—its flavour is not so agreeable. But, it has, on account of the creosote, such

* *Pūr*, fire, Gr.; *lignum*, wood. Lat.

strong antiseptic properties, that meat—to which it will impart a pleasant smoked taste—may be preserved with it.

62. *Hydrated acetic acid*, can be procured, by mixing in a large retort, one part, by weight, of finely powdered acetate of soda—obtained from the neutralized pyroligneous acid—and three parts strong oil of vitriol. The heat, which arises from mixture, causes one-eighth of the acetic acid to distil over of itself: and the process is completed, by the application of a lamp, &c. The last portion of the product, exposed to a temperature below 40°, deposits crystals of hydrated acid—which, being separated from the rather weaker portion, melted with the aid of heat, cooled, and recrystallized, may be considered as pure. Acetic acid, containing one atom water, is called *glacial** acetic acid, since it freezes at about 45°.

Three parts dried acetate of lead, and eight parts oil of vitriol, treated in the same way, give the same results.

63. Hydrated acetic acid, cooled below 62°, crystallizes in transparent colourless broad scales, and tables. Above 62°, it forms a liquid, the specific gravity of which is 1·063: and its density increases, by the addition of water, until it becomes 1·078. It then contains three equivalents ($C_4H_3O_3 + 3Aq$): and further dilution diminishes its specific gravity. Hence, the latter is no test of its strength: indeed, acids of very different strengths may have the same specific gravity. The hydrated acid boils at 240°, and its vapour is inflammable: it fumes in a damp atmosphere, and attracts moisture. It mixes with any quantity of water, alcohol, ether, and essential oils: and dissolves camphor, several resins, &c. *Aromatic vinegar* is acetic acid holding camphor, or essential oils, in solution. Acetic acid is blackened by sulphuric acid—heat being evolved, and sulphurous acid disengaged. When acted upon by chlorine, under the influence of the sun's rays, it forms *chloroacetic acid* ($C_4Cl_3O_3 + Aq$). If its vapour is passed through a porcelain tube, heated to low redness, carbonic acid, and *acetone* (C_3H_3O), are at first produced: and when the temperature is raised, inflammable gases—carbon being deposited.

Anhydrous acetic acid has not yet been obtained.

64. If acetic is adulterated with sulphuric acid, the

* *Glacies*, ice. *Lat.*

latter will be detected by nitrate of barytes [inorg. chem. 309]. If it contains nitric acid, it will give a yellowish colour to indigo, when boiled with that substance: and, if tartaric acid, it will, with nitrate of silver, throw down a precipitate soluble in nitric acid. Ordinary vinegar, almost always contains traces of sulphuric, and tartaric acid. The former, is used to prevent the gluten in vinegar made from malt from rendering it mouldy: and a certain amount of it is permitted by law. Red cabbage is blanched when the vinegar used to pickle it contains sulphuric acid.

65. *Tests for Acetic Acid.*—The neutral acetates—but not free acetic acid, give, with nitrate of silver, white crystalline precipitates ($\overline{A}+AgO$), which dissolves freely in ammonia, and sparingly in cold water. Acetic acid, and, still more, solutions of the acetates give, with protonitrate of mercury, a white scaly protoacetate ($\overline{A}+HgO$), soluble in excess:—it dissolves, also, in hot water, but, is reprecipitated, by cooling, in the form of small crystals. The latter have a gray colour, on account of the protoacetate having been partially decomposed, metallic mercury being liberated. Acetic acid, disengaged from the acetates with sulphuric acid, may be very easily recognised by its penetrating odour. If it is heated with equal parts strong sulphuric acid and alcohol, acetic ether ($\overline{A}+C_4H_5O$) will be evolved—and made known by its agreeable smell. The acetates are decomposed at a red heat, the residue being sometimes a metal, and, at others, an oxide:—if the acetate is alkaline, it is changed to a carbonate, and, in all cases, carbon is liberated.

66. *Acetyle* (C_4H_3, or Ac)—not yet obtained—is supposed to be the radical of this acid: and to form various compounds. Thus—

Oxide of acetyle, . . .	C_4H_3O, or AcO—hypothetical
Hydrate of the oxide of acetyle or aldehyd, . .	C_4H_3O+HO, or $AcO+HO$
The hydrogen of aldehyd, replaced by chlorine, gives chloral, ...	C_4Cl_3O+HO
Aldehyd, with an atom of oxygen, gives hydrated acetous or aldehydic acid,	$C_4H_3O_2+HO$, or AcO_2+HO

Acetous acid, with an atom of oxygen, gives hydratic acetic acid, $C_4H_3O_3+HO$, or AcO_3+HO.

67. CREOSOTE:*—$C_{14}H_2O_4$. This substance is one of the products of the destructive distillation of wood. It may be obtained from coal-tar, or crude pyroligneous acid. The tar is to be distilled, till it begins to exhale white vapours of *paraffine*. The liquor which is condensed, contains water, with a light oil above, and a heavy oil below:—the latter, is the part available for the production of the creosote. This, having been saturated with carbonate of potash, is allowed to settle; and the oily matter at the top of it is decanted off, and distilled. The products of the distillation will ultimately contain an oil heavier than water, which is to be separated from the lighter products, agitated frequently with fresh quantities of dilute phosphoric acid, to remove the ammonia; and then washed with water, to remove all acidity: after which, it is to be distilled with fresh dilute phosphoric acid, the result of distillation being frequently poured back into the retort. The oily liquid, finally obtained, contains *eupione*, &c., and being mixed with solution of caustic potash, specific gravity 1·12, to dissolve the creosote, the supernatant fluid must be decanted off. When the alkaline solution has become dark, by exposure to the air, on account of some foreign matters being decomposed, sulphuric acid is added to separate the potash and the liberated creosote is removed, and distilled. The addition of the caustic potash, &c., is to be continued, until blackening is no longer produced by exposure to the air; after which, the strongest solution of caustic potash must be employed; and the result must be distilled, and even redistilled—the first products being rejected, and the process not being carried too far.

68. Creosote is an oily colourless liquid, having a penetrating odour of smoke, and an acid taste. Its specific gravity is 1·037. It boils at 398°, and burns with a smoky flame. 100 parts water dissolve a little more than one of creosote: and ten parts of the latter, dissolve one of the former. Creosote mixes, in every proportion, with ether, alcohol, and acetic acid. It coagulates albumen, and thus

* *Kreas*, flesh; and sozo, I save. Gr.

prevents the putrefaction of fish, and meat: this, however, is not the only reason why it prevents it: since, without creosote, pure fibrine will putrefy. It is a non-conductor of electricity, and a powerful refractor.

69. Formic* Acid:—*symb.* C_2HO_3, or FoO_3; *equiv.* 37. It was discovered, by the red colour of endive, found in the nest of the *red ant*. Gehler, first recognised it as a distinct acid; and Dobereiner, first prepared it artificially. It may be procured from ants: and it is one of the products of the distillation of vegetable substances with nitric, iodic, periodic, or permanganic acid; or, with a mixture of chromic and sulphuric acids and peroxide of manganese. It may be conveniently obtained, by mixing one part starch, or sugar, with four parts black oxide of manganese, four parts water, and four oil of vitriol. Since the carbonic acid is disengaged so as to cause great effervescence, a retort large enough to hold ten times as much as the mixture, should be used: and the sulphuric acid should be added gradually—the starch (or sugar) manganese and water, having been heated to 104°. When the frothing has ceased, heat is again applied; and, four and a-half parts having distilled over, the acid liquor is boiled with carbonate of lead. On cooling, crystals of formiate of lead ($FoO_3 + PbO$) will separate. They are to be dried, and powdered: and then introduced into a long glass tube, one end of which is connected with a receiver, and the other with an apparatus for disengaging sulphuretted hydrogen. As soon as the formiate of lead has become perfectly black, it is entirely decomposed: and the hydrated formic acid may be driven into the receiver, by a *very* gentle heat: the excess of sulphuretted hydrogen is to be expelled, by boiling. If the acid liquor is neutralized with carbonate of soda, instead of lead, and concentrated, crystals of formiate of soda will separate: and formic acid may be disengaged from them, by sulphuric acid, in the same manner as acetic acid is obtained [62] from acetate of soda.

70. The formic acid obtained in this way, is combined with an atom of water. It is a clear, colourless, and very caustic liquid, of a penetrating odour; it fumes slightly,

* *Formica*, an ant; on account of the source whence it was formerly obtained.

and attracts moisture from the atmosphere. Its specific gravity is 1·235. Cooled below 32°, it crystallizes in brilliant scales: it boils at 212°; and its vapour is inflammable —burning with a blue flame. It mixes with any quantity of water; but an additional atom changes it to the second hydrate (FoO_3+2HO). The specific gravity of the latter is 1·1104: it may be cooled below 5°, without solidifying; and it does not boil till 223°. This hydrate may be made, by distilling, in a chloride of calcium bath, eighteen parts dry formiate of lead, six parts oil of vitriol, and one part water. Like the other, when placed on tender parts of the skin, it causes wounds that are cured with difficulty.

71. *Tests for Formic Acid.*—Concentrated solutions of alkaline formiates give, with nitrate of silver, a sparingly soluble white crystalline precipitate (FoO_3+AgO), which, on being heated, immediately becomes dark, from the presence of metallic silver. $C_2HO_3+2AgO=2CO_2+HO+2Ag$. Similar results would be obtained, with protonitrate of mercury. These reductions are perceived, also, in solutions of formic acid, and dilute solutions of alkaline formiates—although a formiate of the metal is not thrown down. If formic acid is heated with excess of peroxide of mercury, or peroxide of silver, carbonic oxide, and water, are formed—the metallic oxide being reduced. Boiling, causes the whole of the silver, or mercury, to assume the metallic state. This enables us to distinguish formic from acetic acid; and to separate the latter—since it affords acetates which remain in solution. Like the acetates [65], the formiates are decomposed by a red heat—the residue being, according to circumstances, a metal, an oxide, or a carbonate.

72. *Formyle* (C_2H, or Fo)—not yet obtained—is supposed to be the radical of this acid: and to produce various compounds. Thus—

Oxide of formyle,	C_2HO or FoO—hypothetical
Hydrated formic acid,	C_2HO_3+HO, or FoO_3+HO
Protochloride of formyle,	C_2HCl or $FoCl$
Bichloride of formyle,	C_2HCl_2 or $FoCl$ or $FoCl_2$
Perchloride of formyle or "chloroform,"	C_2HCl_3 or $FoOCl_3$
Hydrochlorate of chloride of *formyle*,	$2C_2HCl+HCl$ or $2FoCl+HCl$

Periodide of formyle,	C_2HI_3 or FoI_3
Perbromide of formyle,	C_2HBr_3 or $FoBr_3$
Sulphuret of formyle or "sulphoform," probably,	C_2HS_3.

73. TARTARIC* ACID:—*symb.* $C_8H_4O_{10}$, or $\overline{T}$; *equiv.* 132. It was first obtained by Scheele: and is supposed to have been the earliest discovery of that celebrated Swedish chemist. It is found in the juice of the grape, in the tamarind, and sumac, in sago, and in many fruits—particularly when they are not too ripe. Combined with potash, it forms "tartar," the hard incrustations, perceived on the lower sides of the barrels in which several species of wine are kept—especially those of France, of the Moselle, and of the Rhine.

74. Tartaric acid is procured, by adding one part lime, to four parts cream of tartar ($2\overline{T}+KO$) dissolved in water: tartrate of lime is precipitated, and neutral tartrate of potash ($\overline{T}+KO$) remains in solution. The latter is decomposed with chloride of calcium—which throws down the remainder of the tartaric acid, in combination with lime. The tartrate of lime is collected, washed, and digested with oil of vitriol, equal in weight to half that of the cream of tartar employed, and diluted with four parts water. After the mixture has boiled for a while, it is strained, and gently evaporated to a pellicle. The tartaric acid will crystallize, on cooling, unless tartrate of lime, or free sulphuric acid, is present. The crystals are colourless, if pure. When brown, they are decolourized, by animal charcoal.

75. Tartaric acid is bibasic: the crystals contain two atoms of water. It does not change, by exposure to the air. It is soluble in alcohol: and dissolves in half its weight of water, forming a very acid solution, which becomes mouldy by keeping:—if it is long exposed to the air, or is boiled with oxide of silver in excess, it absorbs oxygen, and forms carbonic and acetic acids. A strong solution of caustic potash, at a high temperature, changes it into acetic and oxalic acids, which combine with the potash. $C_8H_4O_{10}=C_4H_3O_3+2C_2O_3+HO$.

* On account of being obtained from "tartar:" so called, from *the Tartarus* of mythology—because this salt is deposited on the *lower parts* of the cask.

76. The presence of tartaric acid, in solutions containing certain metallic oxides, prevents precipitation by alkalies—on account of tartrates, not decomposed by alkalies, being formed. It acts in this way, with alumina, peroxide of iron, protoxide of manganese, &c.

77. Tartaric acid is often used in medicine, &c. *Sedlitz powders* or "carbonated effervescing Cheltenham salts," consist of tartaric acid, and bicarbonate of soda, in the proportions of their atomic weights. Sometimes, a little sulphate of magnesia (Epsom salt), or tartrate of potash and soda (Rochelle salt), is added.

78. *Tests for Tartaric Acid.*—Chloride of calcium throws down, from solutions of neutral tartrates, a white precipitate ($T+CaO$), the separation of which is retarded by the presence of ammoniacal salts. A solution of caustic potash keeps tartrate of lime in solution, while it is hot, but abandons it when cool. Tartrate of lime is precipitated by lime water, from solutions of the neutral tartrates—or even from tartaric acid, if enough to produce an alkaline reaction is added. Free tartaric acid gives a sparingly soluble bitartrate, with caustic potash [inorg. chem. 623]: and, still more readily, with acetate of potash.

79. When tartaric acid is cautiously heated, it becomes *tartralic acid* ($C_{12}H_6O_{15}+2HO$)—an amorphous mass, like gum, which, after a while, again becomes tartaric acid. If it is kept a considerable time, at a temperature of 360°, it becomes *tartrelic acid* ($C_{16}H_8O_{20}+2HO$), which, unlike tartralic, forms insoluble salts with lime, and barytes. A still longer continuation of the heat, produces *anhydrous tartaric acid* ($C_8H_4O_{10}$), a porous white mass, which is insoluble in water, or alcohol: and changes—gradually, by contact with water, but rapidly by boiling with caustic potash—into tartrelic, tartralic, and, ultimately, tartaric acid. Raised to the temperature of 400°, tartaric becomes *pyrotartaric acid* ($C_5H_3O_3$), water, and carbonic acid, being produced. $C_8H_4O_{10}=C_5H_3O_3+HO+3CO_2$. Pyrotartaric acid is monobasic.

80. Racemic* Acid, called also *paratartaric*, has the same constitution, and nearly the same properties, as tartaric acid.

* *Racēmus*, a bunch of grapes. Lat.

It has been found, only about the Vosges mountains—and even there, but occasionally. It occurs as biracemate of potash, which like the bitartrate, is a very sparingly soluble salt. It is bibasic, and its crystals contain four atoms of water. It differs from tartaric acid, in forming, with lime, a compound, which is insoluble in tartaric acid, or sal-ammoniac. Also, the neutral paratartrates, unlike the neutral tartrates, give a precipitate with gypsum. Racemic acid is changed, by heat, precisely in the same way as the tartaric, except that pyroracemic acid is $C_6H_2O_5$. The corresponding results of both acids have, however, different properties. A crystal of protosulphate of iron becomes of a bright red colour, in the solution of a pyroracemate.

81. CITRIC* ACID:—*symb.* $C_{12}H_5O_{11}$, or $\overline{Ci}$; *equiv.* 165. It was first accurately described by Scheele, in 1784—being, until his time, confounded with tartaric acid. It is found in many fruits, but most abundantly—along with sugar, mucilage, acetic, and a small quantity of malic acid—in the lemon: and may be obtained by straining lemon juice, heating it nearly to the boiling point, gradually adding pulverized chalk in excess, and boiling until the citrate of lime completely separates. The supernatant fluid—which contains the mucilage—is then removed; and the citrate, after being washed on a filter—to take away the sugar, &c.—is decomposed with oil of vitriol, equal, in weight, to the chalk which has been used, and diluted with six times its volume of water. If the resulting solution of citric acid, having been filtered from the sulphate, is concentrated to a pellicle, at 212°, it will afford, while hot, crystals which contain three atoms of water. If they are produced by evaporation at a lower temperature, and slow cooling, they will have two additional atoms: but will lose them by exposure to a gentle heat, or by being placed, *in vacuo*, with oil of vitriol.

82. Citric acid is bibasic. It is sparingly soluble, in alcohol: but it dissolves in less than its weight of cold, and in half its weight of boiling water: the solution, however, like that of tartaric acid [75], will not keep. It has an agreeable sour taste; and is much employed in medicine. *It has* been found of great value in preventing sea scurvy,

* *Citreum*, a lemon. Lat.

so destructive to mariners, in long voyages: and is used in "effervescing draughts," to disengage the carbonic acid from the carbonate of soda. For this purpose, one part citric acid, and nineteen parts water, afford an excellent substitute for the juice of the lemon—particularly, if a little sugar, and a few drops of the oil of lemons, are added. Citric, being one of those acids which form a soluble compound with oxide of iron, it is often employed to remove "iron moulds" from linen, &c. It is very much used, by calico printers: and is, sometimes, adulterated with tartaric acid—which may be discovered, by dissolving it in water, and slowly adding a solution of carbonate of potash. If tartaric acid is present, the sparingly soluble bitartrate will precipitate.

Citric, like tartaric acid [76], prevents some metallic oxides from being precipitated by potash.

83. *Tests for Citric Acid.*—Neutral citrates, in solution —but not free citric acid—give, with chloride of calcium, a white citrate ($\overline{Ci}+CaO$), which is soluble in sal-ammoniac, unless boiled with it; in which case, basic citrate $\{[(\overline{Ci}+3CaO)+CaO]+Aq\}$, is thrown down. Citric is distinguished from almost every other organic acid, by affording, whether free, or in combination, if boiled with lime water, a basic citrate, which is re-dissolved when the liquor cools. Acetate of lead, in excess, gives, with citric acid, a precipitate ($\overline{Ci}+PbO$) soluble in citrate of ammonia. And citric acid in excess gives, with acetate of lead, a precipitate which dissolves on adding ammonia: because citrate of ammonia is formed. Citric acid, and the citrates, acted on, at a high temperature, by sulphuric acid in excess, produce carbonic oxide, and carbonic acid, at first: but, after some time, the fluid becomes discoloured, and sulphurous acid is evolved.

84. When citric acid is heated till a pellicle forms, a new acid, the *aconitic** ($C_{12}H_3O_9+3HO$), is produced, along with *acetone* (C_3H_3O), and a mixture of carbonic oxide and carbonic acid. The same acid is found, in combination, as aconitate of ether ($C_{12}H_3O_9+C_4H_5O$), when citric acid and alcohol, are acted upon with sulphuric acid.

* *On account of having* been found in the aconitum napellus.

If aconitic acid is boiled, carbonic acid is evolved, and *itaconic* acid ($C_{10}H_4O_7+2HO$) passes over, and crystallizes on cooling. When itaconic acid is redistilled, water, and *citraconic* acid ($C_{10}H_2O_5+HO$), are produced:—the latter placed in contact with water, combines with another atom of that fluid.

85. Malic* Acid:—*symb.* $C_8H_4O_8$, or $\overline{M}$; *equiv.* 116. Malic acid exists, to a considerable amount, in the juice of apples, which owe their sourness, chiefly, to it; and is found, more or less abundantly, in other fruits—such as the plum, currant, blackberry, raspberry, strawberry, cherry, &c. It is contained, also, in the berries of the mountain ash; but was, at first, called *sorbic acid*,† when derived from that source, being considered an acid distinct from the malic. It may be obtained, by nearly saturating the juice of the berries of the mountain ash, with lime; boiling the liquor for some hours, to precipitate the malate of lime: and, when the latter ceases to be thrown down, adding a little lime—to complete the precipitation. The whole of the malate is obtained on cooling: and is to be dissolved, by boiling in as little dilute nitric acid as possible. Malate of lime will separate, in crystals, when the temperature falls: and, having been purified by re-crystallization, it is to be decomposed by acetate of lead. When the resulting malate of lead is acted upon with sulphuretted hydrogen, sulphuret of lead, and malic acid will be obtained. The latter, is evaporated, and forms, on cooling, a syrupy liquor which, after resting some time, becomes a white crystalline mass.

86. Malic acid is bibasic: and, in the formation of salts, has a great tendency to retain one atom of basic water. It is without odour, but is extremely acid to the taste: it is deliquescent, and very soluble, in water.

87. *Tests for Malic Acid.*—Solutions containing malic acid, either free, or combined, give with chloride of calcium, on adding alcohol, a white malate ($\overline{M}+CaO$). Acetate of lead, throws down a white malate ($\overline{M}+PbO$,) remarkable for melting in the water in which it is sus-

* *Mālus*, an apple tree. *Lat.*
† From *sorbus aucuparia*, the mountain ash.

pended, at a less temperature than 212°: and then appearing like resin, fused under that liquid. This property is impaired, or destroyed, by the presence of other salts of lead. Malic is distinguished from the tartaric, racemic, citric, and oxalic acids, by giving no precipitate with lime water—even when heat is applied.

88. If malic acid is heated to 400°, it loses its water: and forms two acids, which are isomeric ($C_8H_2O_6$). One of them, the *maleic*, passes over in distillation, along with the water, and crystallizes on cooling:—it has been supposed identical with aconitic acid [84]. The other, *fumaric acid*,* remains in the receiver, and cools into a crystalline mass. It is found in Iceland moss: and gives, with nitrate of silver, a precipitate soluble in nitric acid —but so insoluble in water, that it will be thrown down from that fluid, when it contains only the 200,000th part fumaric acid. If hydrochloric acid gas is passed into malic acid and alcohol, fumaric, and not malic, acid is found in combination with ether.

89. Tannic† Acid or Tannin:—*symb.* $C_{18}H_5O_9$, or $\overline{Qt}$;‡ *equiv.* 185. This substance was long known, under the name of *astringent* principle. It is found in dried grape seed, in the bark of all perennial trees—and, indeed, to a greater or less extent, in all trees, and shrubs. It is very abundant in the oak, and horse chestnut; but its principal source, is the gallnut of the former. It may be obtained, by putting powdered nut-galls and some ether of the shops—because it contains water—in a globular funnel A, fig. 29, having a stopper E, and terminating below, by a tube in which some cotton has been placed, and which rests in the neck

Fig. 29.

* Because first found in the *fumaria officinalis*.

† Because effective in the conversion of skin into leather.

‡ The *acidum quercitanicum*:—from quercus, an oak. Lat.

of the bottle B. After some days, the tannic acid wil found in B, dissolved in the water, which was associ with the ether:—the latter floats above, and contains a t of tannic, and gallic acids. The aqueous solution, ha been washed, two or three times, with ether, is pl under an exhausted receiver; and the result will yellowish white crystalline mass, consisting of tannic combined with three atoms of water.

90. Tannic acid is tribasic. It is not deliquesc but it dissolves in water, with great facility. It is sol in alcohol, and ether—unless, perhaps, when they are anhydrous. Tannic acid is very important, as a test other substances; and is generally used as "infusion "tincture of galls."

91. Artificial tannin may be obtained, by mixing part of any vegetable substance, with five parts o vitriol: letting the mixture rest for some days; then h ing it, as long as sulphurous acid is evolved: afterw washing away the acid, from the residual black mass, water: finally drying the result, dissolving out the ta with alcohol, and evaporating the dark brown solut An extractive matter remains, which has an astrin taste, dissolves in water, and precipitates gelatine— not the salts of iron. Artificial tannin may be for also, by boiling carbon in nitric acid, evaporating solution to a syrup, mixing the latter with water, filter and evaporating;—the residue, a hard, black mass, w is soluble in water, and alcohol, contains nitrogen, precipitates most of the metallic salts, brown. A de tion of coffee berries, after being roasted, gives tan formed, probably, or developed during the roasting.

92. *Tests for Tannic Acid.*—It forms an insoluble, putrescible precipitate, with a solution of glue, or isingl —this precipitate is *leather*. It may exist, in a co nation, from which gelatine will not liberate it, wit the addition of a dilute acid. Tannic acid, in solut exposed to the air absorbs oxygen, evolves carbonic a and becomes coloured: gallic acid being produced.

93. The colour obtained by means of tannic acid the persalts of iron, when very intense, is nearly bl *It is particularly* valuable to the dyer. Tannate of

suspended in a solution of gum, constitutes writing ink. If ink becomes, gradually, of a darker colour, it arises from the peroxidation of the iron, and the consequent formation of an additional quantity of tannate. The tannic acid of some plants produces, with iron, a green combination.

94. Tannic acid forms an insoluble, and, therefore, inert compound with antimony. Hence, it is often used as an antidote to "tartar emetic" (tartrate of potash and antimony: $C_8H_4O_{10}+SbO_3+KO+2Aq$).

95. Manufacture of Leather.—The first part of the process, consists in removing the hair from the skins. This is facilitated by incipient putrefaction, caused by a smouldering fire, kept up in the apartment along with them; or by the action of lime. They are, then, impregnated with the tanning principle contained in oak bark, &c. This is effected, either by leaving them for some time in a pit containing bark and water, layers of ground bark having been placed between them; or, by steeping them in water holding the "tanning principle" in solution. A weak liquor must be used, at first: or, the surface of the skin becoming impervious, the interior will not be tanned. Skins are tanned much more rapidly, by the latter process; but the leather produced, is believed not to be so durable. The greater the quantity of extractive matter which, along with tannic acid, enters into combination with the leather, the better.

Animal bodies remain undecomposed, in bogs, for a long time; being preserved by the antiseptic properties of the tannic acid:—they undergo changes, somewhat analogous to the alteration produced in the skin by tanning.

96. *Tawing* is very different from tanning. Skins are "tawed," by being impregnated with a mixture of alum and common salt. The latter, causes alumina to combine with the gelatine—which decomposes the chloride of aluminum, at first formed. They are next put to ferment, in a vessel containing bran and water; then dried, and finished. A white, and flexible leather, is obtained by this method.

97. Gallic* Acid:—*symb.* C_7HO_8, or $\overline{G}$; *equiv.* 67.

* Thus named, because it was obtained abundantly from nut-galls.

It has been found in nature, ready formed, only in the seeds of the *mango;* but it may be procured from a great variety of sources. It was long known that infusion of galls, oak bark, shell of the walnut, &c., are capable of giving a black precipitate with salts of iron; but the nature of the substance, which produced this effect, was not understood, until the academicians of Dijon in 1772 pronounced it to be an acid. The mode of separating it, from the other substances found along with it, was not discovered for a considerable time after Scheele, in 1780, published a method of obtaining gallic acid. He conceived it to exist in galls; and was not aware that a new acid was formed, during the process he employed.

98. Gallic acid is generated by the decomposition of tannic acid [89], oxygen being absorbed, water formed, and carbonic acid evolved. $C_{18}H_5O_9+O_8=2C_7HO_3+3HO+4CO_2$. For this purpose, a thin paste, consisting of powdered galls and water, is exposed to the air, for some weeks, at a temperature of about 80°—the fluid, evaporated, being occasionally replaced. The mass is then boiled with water; and, on cooling, gallic acid will separate from the liquor, in the form of crystals. The latter, being digested at a moderate temperature with ivory black, and re-crystallized, are colourless. Gallic acid may be obtained, in other ways, more easily, and rapidly, but not in such a state of purity.

99. It is a bibasic acid. Its taste is sour, and astringent. The crystals contain three atoms of water, one of which is removed by a temperature of 230°, and the others, only by bases. They dissolve in their own weight of hot alcohol: in three times their weight of hot, and 100 times their weight of cold water. Gallic acid reddens litmus paper: but, although it decomposes many salts which contain a powerful acid—sulphate of the peroxide of iron, for example—it is unable to expel the carbonic acid, from carbonate of barytes.

100. *Tests for Gallic Acid.*—Unlike tannic acid, it does not throw down gelatine. It gives, with persalt of iron, a blackish blue precipitate, which becomes colourless, by degrees—on account of the decomposition of the *acid,* and reduction of the iron to protoxide, carbonic acid

being evolved. This change is caused at once, by boiling. An alkaline solution of gallic acid, exposed to the air, absorbs oxygen, and becomes yellow, green, red, brown, and lastly, almost black.

101. When gallic acid is heated to 400°, it is decomposed into *pyrogallic* ($C_6H_3O_3$), and carbonic acids. If it is heated to 450°, water is given off, and *melangallic* acid* ($C_{12}H_3O_3$), in the form of a shining black substance, is produced. It is altogether decomposed, at 500°.

102. The mass, from which the gallic acid was dissolved out [98], will be found to contain *ellagic acid* ($C_7HO_3+HO+Aq$). It may be obtained, by digesting with potash, and precipitating with hydrochloric acid. It is one of the constituents of the *bezoar* stones of India, the intestinal concretions of certain animals. Gallic acid—but not ellagic acid—heated with oil of vitriol, gives, on cooling, *parellagic acid.* It is in the form of dark crystals; and has the same constitution as ellagic acid.

CHAPTER VII.

Constituents, &c., of Oils and Fats, 103.—Glycerine, 107.—Stearic Acid, 110.—Margaric Acid, 116.—Oleic Acid, 119.—Butter, 126.—Spermaceti, 130.—Wax, 132.—Soaps, 133.—Manufacture of Soap, 138.—Resin, 142.—Caoutchouc, 148.—Gutta Percha, 153.—Starch, 154.—Lichenine, 158.—Gum, 159.—Sugar, 162.—Lactine, 171.—Mannite, 173.—Diastaste, 174.—The Vinous Fermentation, 176.—Brewing, 180.—Distillation, 188.—Alcohol, 191.—Ether, 202.—Manufacture of Bread, 209.—Lignine, 213.—Gun Cotton, 214.—Extractive Matter, 217.—Gluten, 218.—Vegetable Albumen, 220.—Legumine, 221.—Fibrine, 222.—Animal Albumen, 223.—Caseine, 226.—Vegetable Jelly, 231.—Gelatine, 232.—Ozmazome, 234.—Vegetable Alkalies, 235.—Salicine, 236.—Caffeine, or Theine, 238.—Piperine, 240.—The Putrefactive Fermentation, 241.—Last Products of Decaying Vegetable Matter, 254.

103. Constituents, &c., of Oils, and Fats.—The fixed, are distinguished from the volatile oils, by being incapable of distillation, without being decomposed. Most

* *Melas*, black. Gr.

of the essential oils, seem to be compounds of a hydro- carbon and an oxyhydrocarbon: the latter often being in the solid form, and constituting a kind of camphor. Ber- zelius calls the fluid constituent *elaioptene*,* and the *stearoptene*.† Sometimes, the constituents are separated by cold, and sometimes, but not so perfectly, by distil- tion—the more volatile elaioptene carrying over a long it some of the stearoptene. Fused caustic potash re the whole of the oxygen, and some of the carb- on essential oils, as carbonic acid.

104. Fixed oils, and fats, are compounds of *g*- the oxide of *glyceryle* ($C_6H_7O_4$; *symb.* $\overline{Gly}$), wi- rally speaking, the *stearic*, *margaric*, and *oleic* a- stearate, margarate, and oleate of glycerine being respectively, for the sake of brevity, *stearine*, *ma-* and *oleine*. Fixed oils, and fats, are found, pr- in the cellular membranes of animals; in the se- sules, and the pulp surrounding the seeds of plant contain about 50 per cent. oil: hempseed, 25 p- and linseed, from 20 to 25 per cent. All the fi- when fluid, leave a permanent greasy stain o- When fat oils are raised to near their boiling poi- begin to be decomposed, vapour of water being fi- off, at about 600°: then, as the temperature rises, a- inflammable oil escapes: then carburetted hydro- carbonic acid. Acids decompose them, by combin- their glycerine; and alkalies, by setting it free- being formed. Acetic, hydrochloric, or carbonic ac- water containing chlorine, form compounds wi- matters, and render them insoluble in boiling caus- Hence, greasy stains in goods bleached on the gr- sometimes rendered indelible. An exposure mere- cient to make the grease absorb oxygen, so as to *becom* margaric, &c., acid, facilitates their removal with an alka- Sulphuric or nitric acid, has not the same effect, but caus- the evolution of gas. Sulphuric acid, throws down from several fat oils a dark green, or brown, colouring matter which separates gradually and, being removed, leaves the oil more limpid, and better for burning—particularly if it

* *Elaion*, oil; and ptenos, volatile. *Gr.*
† *Stear*, fat; and ptenos. Gr.

hed with steam, and filtered, or allowed to rest, finally dried with a water bath. Stearine causes to be firm, and solid; when margarine predomi- it imparts the consistence of lard; but, when oleine xcess, fat assumes the liquid form. Sometimes, these ubstances are present, at the same time; but never n two of them. Human fat, goose fat, and olive tain only margarine and oleine. Unless a volatile id—such as the *butyric*, or *hircic*—in combination e oxide of glyceryle, is present, fixed oils, and fats, ost always without smell. When they are ren- mpure, by the presence of mucus, albumen, &c., come rancid, by the absorption of oxygen, and the ion of, probably, an acid—since it is removed by alies. Fats cannot, by any means yet known, be artificially from glycerine and the fat acids.

Oils, and fats, are divided into those which do not en exposed to the air, and those which, by absorb- ygen, and again giving out some of it as carbonic come a dry, tough, and transparent varnish. Olive ond oil, rapeseed oil, &c., belong to the former: Seed oil, poppy-seed oil, nut oil, &c., to the latter. ry much more rapidly, if their impurities are de- by boiling: particularly if litharge is added: or, still better, if they are agitated with water, litharge, -acetate of lead—for their impurities will then sub- d a little oxide of lead will be retained, which im- them. The litharge combines with, and coagulates, le mucus, which would prevent the oil from drying kly. Fish oils, in some respects, resemble the dry- s; but they contain one or more oily acids—gene- he *phocenic*.

Drying oils, when exposed on a large surface—such vings, wool, cotton, &c.—absorb oxygen so rapidly en, to produce spontaneous combustion. In this way, factories have been set on fire, by "cotton waste," o wipe the oil from machinery, &c. Fixed oils, and re insoluble in water; but soluble in oil of turpen- nd, to a certain extent, in alcohol, and ether. They ve sulphur, phosphorus and, generally speaking,

We are chiefly indebted to the admirable researches of Chevreul, for our knowledge of the real nature of oils and fats; and of their compounds.

107. GLYCERINE* or the hydrated oxide of glyceryle: —*symb.* $C_6H_7O_5+HO$, or $\overline{G}ly O+HO$. It was discovered by Scheele: and may be obtained, by heating equal parts olive oil, and finely ground litharge, with a little water: and keeping the mixture well stirred. When it has assumed the consistence of a plaster, water being added, it is removed from the fire: and the liquid, after being decanted off, is freed from any lead it may contain, by transmitting sulphuretted hydrogen through it, and filtering. It is then concentrated as much as possible, in a water bath; and dried, *in vacuo*, with sulphuric acid.

108. Glycerine is a colourless syrup, which has never been solidified. Its specific gravity, is 1·26. It is insoluble in ether; but dissolves in alcohol, and water—which it even absorbs from the atmosphere. By combining with two atoms of sulphuric acid, it forms *sulpho-glyceric* acid ($C_6H_7O_5+2SO_3+HO$).

109. Glycerine has not, in all circumstances, exactly the same constitution. But, if the glycerine of nutmeg butter (C_3H_4O) is taken as the true anhydrous glycerine, the others may be looked upon as combinations, or hydrates of it. Thus, the glycerine of palm oil ($C_6H_4O_2$) may be two equivalents of the anhydrous; and the glycerine of ordinary fats, that of palm oil plus three atoms of water. Berzelius would consider the glyceryle of nutmeg butter, as the oxide of a radical (C_3H_3; *symb.* *Lp*) named by him *lipyle*.

110. STEARIC† ACID:—*symb.* $C_{68}H_{66}O_5$, or $\overline{St}$. It was discovered by Chevreul, in 1811: and may be obtained, by saponifying, with potash, *stearine* (stearate of glycerine) —the residue, when mutton suet is washed with ether as long as any thing is dissolved; then precipitating the stearic acid, by means of warm dilute hydrochloric acid, washing the precipitate with water, and dissolving it in boiling alcohol. The acid will separate from the latter, on cooling, in brilliant white plates: and is purified, by repeated crystallization from hot alcohol.

* Γλυκὺς, sweet, Gr.; since glycerine is the sweet principle of oils.
† Stear, tallow. Gr.

111. Stearic acid is bibasic; and its crystals contain two atoms of water:—the *bi-stearates* consist of one atom of water, and one atom of fixed base; and the *neutral stearates*, of two atoms of fixed base. It is without taste, or smell. When liquid, and at 170°, its specific gravity is 0·854. It congeals, at 158°, into a crystalline mass, the specific gravity of which is 1·01. It is insoluble, in water: but dissolves, in hot alcohol, and the solution reddens litmus paper.

112. In the cold, stearic acid partially decomposes the alkaline carbonates, forming a bicarbonate, and an acid stearate: at a boiling temperature, it expels the carbonic acid, and forms a neutral stearate. The latter is decomposed by 1,000 parts water, into potash, and the acid stearate—which is insoluble in water, but soluble in alcohol. If the acid stearate is removed, 1,000 parts boiling water will change two atoms of it, into one atom of still more acid stearate ($2St+KO+3HO$), which remains suspended in the water, and an atom neutral stearate, which is dissolved by it.

113. Stearic acid, under the influence of heat, seems to distil over unaltered, since it condenses into a substance, having nearly the same melting point. It has, however, been entirely changed, *margaric acid* ($C_{34}H_{33}O_3$), and *margarone* ($C_{34}H_{33}O$), being produced. $2C_{68}H_{66}O_5=3C_{34}H_{33}O_3+C_{34}H_{33}O$. If stearic acid is heated with an equal weight of nitric acid, specific gravity 1·25, for a few minutes, large quantities of red fumes are given off: and the stearic is entirely changed into margaric acid, oxygen being absorbed. $C_{68}H_{66}O_5+O=2C_{34}H_{33}O_3$. But if the process is continued, nitric acid being occasionally added, until the fat acid disappears, the liquid, on cooling, will deposit *Succinic* acid* ($C_4H_2O_3+Aq$), as a mass of crystals. And, if the mother liquor, after the succinic acid has been removed, is evaporated to one-half, *suberic† acid* ($C_8H_6O_3+Aq$) will separate, also, as a mass of crystals. The precise manner in which these acids are formed, is not, as yet, well understood.

* *Succinum*, amber, *Lat.*; because obtained by the destructive distillation of that substance.

† *Suber*, cork, *Lat.*; because a product of the oxidation of cork, with nitric acid.

114. When stearic acid is heated, in contact with lime, *stearone* ($C_{68}H_{68}O$), a volatile liquid, is produced. The compound, obtained in this way, by Redtenbacher, seems to be a combination of margarone with one ($C_{12}H_{12}$) of the many carbo-hydrogens, which have different equivalents, although their carbon and hydrogen are in the same proportions.

115. Large quantities of stearic acid, are used in the manufacture of a species of candle, which is very little inferior to wax. The material of which it consists, is obtained by saponifying tallow with lime, mixed with water so as to form a thin paste; then decomposing the resulting soap, with hydrochloric acid, and removing the oleic acid, by pressure between folds of cloth. The tendency of the stearic acid to crystallize, is counteracted—very improperly, however—by the addition of about one part in 2,000 arsenic.

116. MARGARIC* ACID:—*symb.* $C_{34}H_{33}O_3$, or $\overline{Mr}$. It was discovered by Chevreul. To obtain it, the ethereal solution, decanted off in obtaining the stearine [110], is evaporated: and the residue is dissolved in boiling alcohol. *Margarine* (margarate of glycerine), will be deposited, in the crystalline form, on cooling. The process used for obtaining stearic acid from stearine [110], enables us to procure margaric acid in the form of white needles, from margarine. Margaric acid may, also, as we have already mentioned [113], be obtained by oxidizing stearic, with nitric acid. Other oxidizing substances, would produce the same effect.

117. Margaric acid is monobasic: and its crystals contain one atom of water. It differs from stearic acid, by melting at 140°. If it is heated with, or without lime, margarone ($C_{34}H_{33}O$), carbonic acid, a hydrocarbon ($C_{32}H_{32}$), and water, are produced, $2C_{34}H_{33}O_3 = C_{34}H_{33}O + 2CO_2 + C_{32}H_{32} + HO$. Margarone is a white crystalline friable fat, which may be purified, by crystallization from ether. It would appear to consist of two or more bodies, each having the same constitution: since, though it generally melts at 190°, its point of fusion is sometimes as high as 200°, or

* From *margarites*, a pearl, Gr.; on account of the appearance of margarate of potash.

beyond it. If it is repeatedly distilled, from lime, the result is a carbo-hydrogen ($C_{66}H_{66}$), carbonate of lime, and carbon—which is deposited. $2C_{33}H_{43}O+CaO=C_{66}H_{66}+(CO_2+CaO)+C$.

118. It is more than probable, that margarone, as also margaric, and stearic acid, are compounds of a radical ($C_{34}H_{33}$)—which has been termed *margaryle*. If such be the case, their constitution is—

Margarone,	=	$C_{34}H_{33}+O$
Margaric acid,	=	$C_{34}H_{33}+O_3$
Stearic acid,	=	$2C_{34}H_{33}+O_5$

That stearic, and margaric acids, are compounds of the same radical, is rendered the more likely, by the facility with which the former is changed into the latter [113].

119. Oleic* Acid:—*symb.* $C_{36}H_{35}O_3$, or *Ol*. Combined with glycerine, it is the principal constituent of liquid fixed oils, that are not "drying oils." It is almost quite pure, in almond oil; and rather less so, in rape oil. It is found, along with stearic acid, in bile. It may be obtained, by exposing the solution of almond oil in hot ether, to intense cold—which separates any margarine present, in the crystalline form; and, when the ether is driven off, from the clear liquor, by a gentle heat, the residue is oleine (oleate of glycerine), a compound which remains fluid, at 0°. The oleine is saponified with a strong solution of caustic potash; and the oleate of potash, decomposed with hydrochloric acid. The oleic acid, which separates, should be washed, and dried under an exhausted receiver, with chloride of calcium.

120. Oleic acid is monobasic: and is obtained in combination with an atom of water. It is an oily liquid, without colour, taste, or smell. Its specific gravity, at 60°, is 0·898. It dissolves in water; but, still more readily, in alcohol, and ether—and the solutions redden litmus paper. At some degrees below 32°, it becomes a mass of needly crystals. The solubility of oleate of lead, in ether, enables us to separate it perfectly from the stearate, or margarate, of that metal. If the ethereal solution of oleate of lead is mixed with dilute hydrochloric acid, the oleic acid, dissolved in ether, will rise to the surface.

121. When oleic acid is exposed to a high temperature,

* *Oleum*, oil. *Lat.*; from *elaion*, olive oil. Gr.

part of it distils over unaltered; but most of it is decomposed into a number of substances, of which the principal are *sebacic** *acid* ($C_{10}H_8O_3$), carbonic acid, a carbo-hydrogen ($C_{59}H_{59}$), and carbon. $2(C_{36}H_{35}O_3+HO)=C_{10}H_8O_3+2CO_2+C_{59}H_{59}+C$.

122. When oleic acid is acted upon, with the red fumes of nitrous acid, a deep yellow butyraceous mass is produced. If this is digested with warm alcohol, a deep orange red oil is dissolved: and the residue is *elaïdine*, a compound of *elaïdic acid* ($C_{72}H_{66}O_5$), and glycerine. When this is saponified with caustic potash, a soap is produced, from which elaïdic acid, combined with two atoms of water, is obtained, by means of hydrochloric acid. The manner in which the nitrous acid produces the orange red oil, and the elaïdine, is not understood—the composition of the oil not being, as yet, ascertained.

123. Concentrated nitric acid acts so violently on oleic acid, as to produce almost an explosion: and it acts powerfully, at first, even when diluted. On applying heat, a small quantity of an oily fluid, which has a pungent smell, and attacks the organs of respiration, passes over—along with the vapours of nitric, and nitrous acid. If, when a fatty acid no longer separates on cooling, the solution is evaporated to one-half, it will deposit crystals of suberic [113], along with a small quantity of *azolaic* acid (supposed to be $C_{10}H_8O_4+Aq$). These substances having been removed, and the liquor allowed to rest for some time, more suberic acid will be deposited—and, also, *pimelic acid* ($C_7H_5O_3+Aq$), in the form of hard crystalline grains. When these are taken away, and the mother liquor, after being gently evaporated, is allowed to rest for some days, crystals are deposited: and the quantity will be increased, by repeating the evaporation, &c. If these crystals are dissolved in hot water, they will be freed from an oil with which they are associated, and will recrystallize, on cooling. Being then dissolved in ether, and the resulting solutions being evaporated to one-half, *adipic acid* ($C_6H_4O_3+Aq$) will separate; and, when this is removed, and the residual liquor is farther evaporated, *lipic acid* ($C_5H_3O_4+Aq$). If the adipic acid is boiled with alcohol, it will be obtained in rounded

* *Sebaceus*, belonging to tallow. Lat.

ins; and the lipic acid, treated in the same way, in g plates. The nitric acid liquor still contains other sub- nces, not yet examined.

124. On account of the low temperature at which oleine ngeals, it is well adapted for oiling watches, clocks, &c. eam-engines, on the contrary, from the high heat to ich they are exposed, require to be lubricated with sub- nces containing solid fats—which are even rendered still re effective, by the addition of wax.

125. The oleine of the drying oils, contains an oleic acid, t differs from what we have just examined; and by ab- rbing oxygen, is converted into a kind of resinous varnish carbonic acid being evolved. When acted upon by nitric id, it produces, first, a resinous substance: and then ox- c acid.

126. BUTTER.—To separate the butter from the milk, it not necessary that the latter should be sour: if it is ndered alkaline with bicarbonate of potash, it yields its tter more readily than if it is acidulous. In churning, temperature should not be under 50° Fahr., nor so high 60°. During the churning, the temperature rises three four degrees. The French purify their butter, by melt- g it in a water bath, to coagulate the albuminous and rdy matters, which are extremely putrescible; then de- nting, and straining it through a cloth; and rapidly cool- g it, to prevent the crystallization of its stearine, and se- ration of its oleine which would injure both its flavour d appearance. After slightly patting it, they put it into all jars, and cover it well. It will remain nearly fresh, d without any rancidity, for a very long time. Butter ntains—along with stearine, margarine, and oleine—*tyrine*, *caproine*, and *caprine*. The three first, are se- rated by melting the butter, and keeping it, for some ys, at a temperature of 68°. The stearine, and mar- rine crystallize, and the oleine may be dissolved out from residue, with alcohol.

127. When butter is saponified, and the soap is decom- sed by tartaric acid, the butyric, caproic, and capric acids main dissolved: and may be easily removed from the aric, margaric, and oleic—since, on distilling the liquor, ey *pass over, along* with the water.

128. *Butyric acid* ($C_8H_7O_3$) is most conveniently obtained, by dissolving one part sugar, in five of water: and causing the solution to ferment, by a temperature of between 90° and 100°, and the addition of cheese, or animal membrane. *Lactic* acid* ($C_6H_5O_5$) is first produced, one atom of cane sugar, and one atom of water being changed, by catalysis [inorg. chem. 135], into two atoms of lactic acid. $C_{12}H_9O_9+HO=2C_6H_5O_5$. The lactic acid is separated, by adding pure carbonate of lime, occasionally, as long as it causes a precipitate. After a while, carbonic acid, and hydrogen, are evolved: and soluble butyrate of lime is produced from the lactate, butyric ($C_8H_7O_3$) being formed by decomposition of its lactic acid and water. $2C_6H_5O_5+HO=C_8H_7O_3+4CO_2+4H$. The solution of butyrate of lime being distilled with hydrochloric acid, and fused chloride of calcium being added to the product, butyric acid separates, as an oily liquor; and may be purified, by redistillation. The process by which this acid is obtained from sugar, is well calculated to illustrate, how easily fats are formed, in the animal system, from saccharine and other such substances. Butyric acid, boils at above 212°. Distilled with lime, it gives *butyrone* (C_7H_7O), and *butyral* ($C_8H_8O_2$).

129. If the *caproic*† ($C_{12}H_{11}O_3$), and the *capric acid* ($C_{20}H_{19}O_3$)—obtained along with the butyric, from the saponified butter [127]—are distilled over, and neutralized with barytes, the three barytic salts may be separated, by repeated crystallization; and the acids, combined with an atom of water, may be procured from them. The caproic acid has the odour of perspiration, and boils at 396°: its barytic salt crystallizes in long needles. The capric acid has the odour of a goat, and boils at 534°: its barytic salt is insoluble in cold water.

130. SPERMACETI, so called from an erroneous opinion as to its origin, is found—dissolved in spermaceti oil—in cavities of the skulls of different animals belonging to the whale species. After death, it separates from the oil, by crystallization: and may be obtained, quite pure, by dis-

* *Lac*, milk. *Lat.*; because one of the sources whence it is obtained.

† *Capra*, a goat. *Lat.*

ng it in hot alcohol, until the latter takes up no more
It crystallizes from the alcoholic solution, on cooling:
is then termed *cetine*:* it is a combination of *cetylic*
($C_{32}H_{31}O_3$) and *ethal* ($C_{32}H_{34}O_2$). The cetylic acid is
ured, by heating cetine with fused potash and quick-
to 350°: the potash changes the ethal into cetylic acid,
ogen being evolved, and water liberated: and the
e of the cetylic acid forms cetylate of potash, which,
chloride of barium, gives cetylate of barytes, and
with a strong acid, cetylic acid. The latter, may
istilled, unchanged, at 130°. It dissolves in alcohol,
ether.

1. Ethal or hydrate of the oxide of *cetyle* ($C_{32}H_{33}$, or
may be obtained by fusing cetine with half its weight
otash, and digesting the saponified mass with dilute
ochloric acid. The cetylic acid, and ethal, float on the
ce. They may be separated, by adding lime—which
s cetylate of lime: and then boiling with alcohol—
h dissolves the ethal, and precipitates it in the crystal-
form, on cooling. Ethal melts at 119°: and passes off
lly, in the form of vapour, at 250°. Cetylic acid, and
, have been considered, by some, as products of the
nposition of cetine, rather than its elements.

2. Wax.—It has not been ascertained, with certainty,
her this substance is merely collected by bees, or they
apable of producing it from their food. As the ma-
of honeycomb, it is yellow: but it is bleached, by
sure to light in thin ribbons. When boiled with al-
, it is separated into *cerine*† ($C_{20}H_{20}O_2$), which dis-
s, and is precipitated, by cooling, as a mass of fine
es: and *myracine* ($C_{20}H_{20}O$), which is insoluble.
ie is less fusible than wax. It is saponified, by boil-
with potash: and, with the process used to obtain
from spermaceti [130], affords *ceraine*—which, prob-
has the same constitution as myracine. The latter
t affected, by potash. The waxy substance, found on
urface of the sugar cane is termed *cerosine* ($C_{42}H_{50}O$).
not saponified by potash.

3. Soaps are salts of the fat acids. Soap is men-
d by Pliny, who says it was invented by the Gauls,

* *Cetus*, a whale. *Lat.* † Cera, wax. Lat.

and was used to render their hair shining:—he d
seem to have known its detergent qualities.

Hard soaps are made with the fats, and the
Soft soaps, with drying oils—sometimes mixed w
oils. With the same substance, soda gives a hard
than potash. The nature of the fat, also, affects t
sistence of the soap:—thus, potash forms a muc
consistent soap with tallow, than with oil. The m
arate of potash or soda, the harder, and more sol
soap: the more oleate, the less hard, and less solubl
soaps of potash, are more soluble than those of
oleate of potash, dissolves in four parts water; bu
of soda, in not less than ten parts. Potash soaps ar
by the soap-boilers, "soft soaps," even though dri
ficially. They become a soft jelly, by exposure
atmosphere: since stearate, margarate, and oleate o
are deliquescent; which is not the case, with corres
salts of soda. Soft soap is used in washing coars
and in bleaching.

134. Hard soaps are separated from water, duri
manufacture, by the addition of common salt. A sa
solution of the latter will not even wet muscular f
soap immersed in it: and no more of it will adhere
substances, than if they had been dipped in m
When the solution of salt is not saturated, some wa
unite with the soap. *Mottled* soap cannot be co
with more than a certain quantity of water; for
amount were exceeded, the soaps of copper, and
which cause the mottling—would, during manu
have subsided through the soap, on account of its
fluidity. Since mottling is, ordinarily, a proof that
good, it is, in some cases, produced fraudulently. E
to the air, gives mottled soap a reddish tint, by ox
the iron.

135. Soft soaps are separated from the water by
ated alkaline solution. Soap of soda is often form
a soap of potash, by the addition of common salt—
of potassium being produced.

136. The detergent qualities of soap depend on t
that the neutral stearates, margarates, and oleates of
and soda are decomposed by cold, or hot water [U

alkali being set free. It is this alkali that cleanses the clothes, by forming a soap with the unctuous matters, which contaminate them—and which, being thus rendered soluble, are removed by washing. A caustic alkali, dissolved in water, would produce the same effect; but it would injure the texture of the linen, &c. The turbidity of "soap suds," arises from the insoluble acid stearates, &c., held in solution.

137. Since earthy and metallic soaps are, generally speaking, insoluble, the use of "hard" water, in washing, must be very injudicious:—for, not only is the soap decomposed and wasted, but the earthy and metallic soaps, which are formed, attach themselves to the clothes, and can scarcely, if at all, be removed. Carbonate of potash, or soda "softens" the water, by separating any lime which may be present, before the soap is dissolved. Earthy, and metallic, soaps are termed *plasters*.

138. MANUFACTURE OF SOAP.—The alkaline carbonate, whether obtained in kelp,* or [inorg. chem. 647] by decomposition of common salt, is first rendered caustic, by acting on it with lime [inorg. chem. 646]: and the resulting alkaline solution, termed a *ley*, is boiled with the oil or fat, until the entire forms a viscid emulsion, which may be drawn out into threads. Undecomposed oil, or a deficiency of water, would cause turbidity. The soap is separated from the water, by the methods we have already described [134 and 135]: or it is boiled, until the concentration of the ley is such that the soap, being no longer soluble in it, floats on the surface. When the frothing ceases, the separation is known to be complete: and the "grain soap"—as it is called, in this state—may be ladled away into moulds. If it is to be manufactured into "white soap," it must be liquefied with "ley," and the application of heat:—this will cause the impurities [134] to subside: and the soap will take up an additional quantity of water. Grain soap

* The "kelp," or incinerated sea-weed, after having been used by the soap-boiler, still contains chloride of potassium: and is employed by the alum-maker, to change sulphate of iron into sulphate of potash. The latter, combined with the sulphate of alumina of burned *clay slate*, forms *alum* $[(SO_3+KO)+(3SO_3+Al_2O_3)]$.

contains about thirty per cent. of that fluid: and white soap, almost twice as much. When the soap is to remain combined with an undue amount of water, evaporation is prevented, by immersion in brine.

139. *Resin Soap* is formed by the union of resin with alkali—which is very easily effected. An alkaline carbonate will answer for the purpose: and, on adding an excess of the carbonate, or common salt, the soap separates as a slimy brown mass, which smells strongly of resin. It attracts large quantities of moisture from the atmosphere: and, by itself, is a "soft soap:"—but, along with a fatty soap, it forms a hard and useful article.

140. The union of resin with the alkalies, can scarcely be considered as saponification. No glycerine is set free: and the acids of the resin are merely combined, at a boiling temperature, with the alkali, for which they have a yet stronger affinity than the fat acids. And, since the alkali is not neutralized by resin, as it is by tallow, its action on wool and other animal fibres is too strong, if there is not a sufficient quantity of fat along with the resin.

141. The alkalies form saponaceous compounds with hair, wool—and even flesh, fish, &c. Ammonia is evolved in these cases, and the fat acids are produced, more or less gelatine, &c., being mechanically mixed with the resulting soap. In this way, animal substances are completely dissolved by the caustic alkalies. In some instances, the bodies of workmen who, during the manufacture of soap, had unfortunately fallen into the pans, were found to have entirely disappeared—nothing being discovered of them afterwards, but the salts of their bones.

142. RESIN.—Ordinary "white resin," dissolved by oil of turpentine ($C_{20}H_{16}$), exists in different species of pine. When crude resin is distilled with water, the oil of turpentine passes off in vapour: and resin—then termed *colophony*—remains behind. It is, in reality, a mixture of two resins—the pinic, and sylvic acids: they have different properties, but are isomeric, each being $C_{40}H_{30}O_4$.

143. *Pinic* acid*, is obtained by acting on colophony, reduced to a fine powder, with alcohol, specific gravity *0·865*—which dissolves the pinic, but not the sylvic acid.

* *Pinus*, a pine tree. Lat.

The solution is then mixed with an alcoholic solution of acetate of copper, as long as any thing is thrown down. The precipitate, which is pinate of copper, being dissolved in strong boiling alcohol, is decomposed by a little hydrochloric acid. The addition of water liberates the pinic acid, which is to be dried by a gentle heat.

144. Pinic acid is colourless. It softens at 149°, and melts at 257°: dissolved in alcohol, it has an acid reaction. It expels carbonic acid from bases, forming alkaline salts which are soluble, and earthy or metallic salts, many of which dissolve in spirit. Long exposed to the atmosphere, it absorbs oxygen, and forms *oxypinic* acid ($C_{40}H_{30}O_6$). It is decomposed, by lime.

145. *Sylvic acid*,* the residue after the pinic has been separated [142] from colophony, is purified by dissolving it in two parts boiling alcohol, specific gravity 0·865. It separates, on cooling; and is still further purified, by repeated solution.

Sylvic acid melts at 212°. It is soluble in strong alcohol, and ether.

146. Either pinic or sylvic acid, when kept melted for some time, becomes brown, and changes into colophonic acid: a resin which is only sparingly dissolved by alcohol, and exists, to a small amount, in common resin.

147. There are a great variety of resins, differing somewhat in constitution, and properties. *Gum-resins* are soluble in a mixture of water and alcohol.

148. Caoutchouc:—Probably, C_2H_3. It is called, also, "gum elastic," and "Indian rubber:" and is obtained from the milky juice of several plants, which grow in hot countries. A mould of clay is covered with successive coatings of the juice: and, when the covering is sufficiently thick, it is broken, and removed. Caoutchouc, while fresh, is of a yellowish white colour: but it grows dark by exposure to the air.

149. Caoutchouc is remarkable for its tenacity, and elasticity. Threads of it are cut so fine—with a wetted knife—that 32,000 yards are made from one pound. They lose their elasticity, by cold; or by being stretched to about eight times their length: but regain it again, and

* *Sylva*, a wood. *Lat.*

are shortened, when heated with a smoothing-iron. W
caoutchouc is stretched, considerable heat is evolved.
is quite rigid at 40°, melts at 240°, and at 600° is resol
into a vapour, which condenses into *caoutchisine*, an
tremely volatile liquid. The latter dissolves caoutch
and other substances: liquefies oil-paints, without inju
them, causing them to dry with great rapidity; an
used in preparing certain varnishes:—mixed with alco
it dissolves all resins, and even copal, at ordinary temp
tures. It is the lightest liquid known, its specific gra
being about 0·68: but its vapour is heavier than any
Caoutchouc burns with a bright flame; and is use
Cayenne instead of candles. It is insoluble in alcohol,
is soluble in ether quite free from alcohol, and in rect
naptha—obtained from wood, or coal, tar. When
ethereal solution is evaporated, the residue, after b
clammy for awhile, becomes solid. Caoutchouc is pre
tated from this solution, in the milky form, by alcohol
dissolves likewise in the essential oils; but, on accou
the resin they contain, remains viscid after they have
porated. Its best solvent is a mixture containing
parts sulphuret of carbon and 6 or 8 anhydrous alc
It is not acted on by sulphurous, hydrochloric, or fluosi
acid, nor by ammonia; but little by cold sulphuric
dilute nitric acid: nor is it affected by the strongest s
tion of caustic potash, even at a boiling temperature.
kneading caoutchouc, during its manufacture, the alter
contraction and expansion, generates so much heat th
boils the water in contact with it, though quite col
first: large quantities of vapour being emitted. If w
were not used in the process, it would soon become to
to be handled. Caoutchouc is a non-conductor of ele
city. A strip cut from it, and placed in boiling w
contracts in every direction, and seems to be an excep
to the law of expansion by heat [heat, 38].

150. Substances, rendered water proof by caoutch
do not allow the escape of the insensible perspiration:
therefore, are not healthful. When it is used for w
beds, the bed-clothes are wetted by the perspiration, w
has not the usual means of escape.

151. Caoutchouc, heated with sulphur to 250°, or

combines with it, and forms "vulcanized Indian rubber:" a substance remarkable for its great, and permanent elasticity—at all temperatures under the vulcanizing point. It bears a much higher heat than ordinary Indian rubber, and is not affected by any known solvent.

152. There are several species of mineral caoutchouc; but they are less easily dissolved, than what is derived from vegetables.

153. GUTTA PERCHA is the juice of a tree which grows in Borneo—but whose history is not well known. It yields, by distillation, products analogous to those obtained from caoutchouc. Heated to 120°, it may be moulded with the fingers; and it preserves, with great accuracy, when cold, the figures, &c., stamped upon it while in a soft state. It is sometimes used for bands, &c., in machinery: and for the soles of shoes, &c. It may be joined easily, if the parts that are to be united are kept *perfectly* clean, and are not over-heated.

154. STARCH.—The composition of this substance, whatever may have been its source, is $C_{12}H_9O_9+2HO$. It is found abundantly in wheat, potatoes, &c.: and is imbedded in the cellular tissue of the plant, in the form of small white grains, of different sizes—those of a potato, the largest, being the $\frac{1}{250}$th of an inch, and those of arrow root, which are among the smallest, the $\frac{1}{600}$th of an inch, in diameter. These grains are, sometimes, globular: at others, ovidal: and, occasionally, even in the same plant, irregular.

155. Starch may be obtained, by scraping the potato into cold water: then pouring off the milky liquor, and allowing it to settle. The starch will fall down, and may be purified, by washing it again with water, and separating it, as before. The grains of starch consist of concentric layers, increasing in density from the centre. They are insoluble in cold, but—except the outer layers—are soluble in hot water. If the solution is dried at a gentle heat, and the residue is dissolved in cold water, the outer layers may be removed by filtration: after which, the solution will be quite clear. Dried at the temperature of 140°, a solution of starch forms a transparent mass; at 212°, it loses *an atom of its* water, and becomes $C_{12}H_9O_9+HO$;

heated to 240°, it softens, and becomes brown; heated till it smokes, it forms "British gum"—a substance quite insoluble in cold water. Starch gives with iodine a blue [inorg. chem. 363]: and with bromine, a yellow [inorg. chem. 367] precipitate.

156. When a potato is frozen, the cells which contain the starch are burst; and the juice of the epidermis, flowing into the interstices, renders it not only unwholesome, but so unpalatable, that neither man nor beast will eat it. If the potatoes are dried, immediately after being thawed, such an inconvenience will not follow; but, on the contrary, being deprived of their vitality, they will keep for an indefinite period. This method of preserving potatoes has been long used by the Peruvians. Frozen potatoes, will afford very little starch; because the cells, having been separated from each other by the frost, are not torn open, nor are their contents disengaged, by rasping.

157. When starch is obtained from wheat, the latter is made to ferment, and become sour—that the gluten, which would attach itself to the starch, may be removed.

158. LICHENINE, is a species of starch. It is found in many lichens, particularly "Iceland moss," and "Carrigeen." It does not occur in grains, but in solution; and it gives, with iodine, a greenish brown precipitate.

159. GUM:—$C_{12}H_{11}O_{11}$. It is a well-known substance; and is obtained from the juices of many plants. It is of various kinds;—that which is termed *arabine* is found in commerce, as "gum arabic," and "gum senegal." It is soluble in water, forming a liquid called "mucilage;" and is precipitated from its aqueous solution, by alcohol. It forms, with nitric acid, first *mucic acid* ($C_{12}H_8O_{14}$)—by absorbing six atoms of oxygen: and then oxalic acid. It exerts a rotary power [opt. 213], on a polarized ray of light: and it gives a precipitate, with a solution of soluble glass [inorg. chem. 411].

160. *Tragacanthine* or "vegetable mucus," exists in the cherry tree, &c.—but, in its purest form, in "gum-tragacanth." It gives no precipitate, with soluble glass.

161. *Dextrine.*—An artificial gum may be obtained, by keeping five parts starch, one part oil of vitriol, and fifteen parts water, for some time, at a temperature of somewhat

an 200°. The starch disappears: and the resulting
ne may be separated from the sulphuric acid, by
hate of barytes. Unlike ordinary gum, it exercises
tral [opt. 235] rotary power, on a polarized ray.
ine dissolves in water, like gum: and is not affected
line.

. SUGAR.—Under this name, are comprehended all
nces capable of the vinous fermentation:—or, in
words, of being resolved, by a particular species of
position, into alcohol, and carbonic acid. Although
has the same composition as cane sugar, it does not
s this property: nor is it acted on, by fermenting
nces.

ne sugar:—$C_{12}H_9O_9+2Aq$, when crystallized. It is
in the sugar cane, beet root, carrot, turnip, potato,
and in the nectaries of most flowers. To obtain it,
ices from which it is derived are clarified, at the tem-
re of 150°, with lime—which coagulates the veget-
albumen, and checks the fermentation, into which
un with great rapidity. They are then evaporated,
ow a temperature as possible, and placed to cool, in
s having apertures which are temporarily closed. If
mperature is as high as is required under the pres-
f the atmosphere, some of the sugar will be burned,
es being formed. When the syrup has congealed
granular mass, the "molasses," or liquid uncrystal-
part, runs off: and "Muscovado" or raw sugar
is. To purify it still further, it is redissolved: and
lution being evaporated, it is poured into cones of
ed earthenware, which are placed on their vertices
apertures that are in the latter, being stopped with
: while cooling, the sugar is stirred about, to dimin-
size of the crystals. Finally, the plugs are removed,
ie fluid which is still present may run off. The re-
"loaf sugar." If the saccharine solution is left in
n place to crystallize, "sugar candy" is produced.
ong solution of sugar, kept for some time near its
g point, is gradually changed into uncrystallizable
To prevent the waste, which might arise from this
the evaporation [heat 111] is sometimes carried on
uo.

163. Sugar, when quite pure, is colourless. Its crystals are four sided, or irregular six sided prisms, accuminated on two surfaces. Pieces of sugar, rubbed together in the dark, become highly phosphorescent. Its specific gravity is 1·6065. At 350°, it melts into a colourless liquid which, when cooled suddenly, forms "barley sugar." At 630° it gives off water, and becomes *caromel* ($C_{12}H_9O_9$), a dark brown shining porous substance, soluble in water, but insoluble in alcohol, and capable of combining with bases. At a higher temperature, it is decomposed into combustible gases, charcoal, &c. It dissolves abundantly in hot, and in one-third of its weight of cold, water. A saturated solution—called a "syrup"—is, by the presence of a small quantity of oxalic, citric, or malic acid, rendered incapable of forming crystals: and the organic acids, cannot always be removed by alkalies. Sugar acts as a weak acid, and unites with oxides. It forms, with common salt, a compound, of which the constitution is $2C_{12}H_{10}O_{10}+NaCl$.

164. Cane sugar is changed, by dilute sulphuric, or hydrochloric acid, into grape sugar ($C_{12}H_{11}O_{11}+3Aq$); but, by these acids in a concentrated form, into a brown substance, consisting of *sacculmine* ($C_{40}H_{16}O_{14}$), and *sacculmic acid* $C_{40}H_{14}O_{12}$. They are insoluble in water, and alcohol: and are easily separated, on account of the sacculmic acid being dissolved by alkalies, and precipitated from solution, as a brown powder, by acids. Sacculmic acid is converted by boiling for a long time with water, into sacculmine.

165. When sugar is boiled, for a considerable time, with a stronger acid, *saccharo-humine* ($C_{40}H_{15}O_{15}$), and *saccharo-humic* acid ($C_{40}H_{12}O_{12}$), are the results. They are insoluble in water, and alcohol: and may be separated, by dissolving the saccharo-humic acid in an alkali. Unlike sacculmine, and sacculmic acid neither saccharo-humine, nor saccharo-humic acid, can be produced without access of air.

Sugar, heated with lime, forms *metacetone* (C_6H_5O), a volatile liquid.

166. If, in the process for making oxalic acid [31], dilute is used, instead of concentrated nitric acid, the result is a *liquor* which gives, with carbonate of lime, a neutral solu*tion.* When this is decomposed with acetate of lead, a

white precipitate is formed. If the latter is acted upon, with sulphuretted hydrogen, *saccharic acid* ($C_{12}H_5O_{11}$) is set free. It is penta-basic, and may be obtained in the crystalline form, by evaporation, and cooling.

167. *Grape sugar:*—$C_{12}H_{11}O_{11}+3Aq$, when crystallized. This is called, also, "glucose."* It is identical with sugar of diabetes, with sugar of starch, of fruit, honey, &c.: and is the product of germination. Sugar is produced, when hay becomes heated, from not having been thoroughly dried:—and the sweetness of old hay, is probably due to this change having occurred to a slight extent. It can be made from cane sugar, by boiling, for a sufficiently long time, with sulphuric acid: and, from starch, by fermentation. It is produced, by acting upon linen with its own weight of oil of vitriol—without allowing the mixture to become heated. The result is a uniform, viscid mass, which is to be diluted with water, and boiled for some time: after which, the sulphuric acid may be removed, with chalk; and the sugar, purified by crystallization. It is very conveniently obtained, from raisins, or honey, by digesting with cold strong alcohol—to remove the uncrystallizable sugar: then expressing the residue, dissolving it in water, and neutralizing the solution with chalk: after which the liquor may be clarified with white of egg, and evaporated until crystals are formed.

168. Grape sugar is less soluble, and less sweet, than cane sugar. It is very soluble in cold alcohol; but, when dissolved in hot alcohol, it combines with the latter, and precipitates, almost entirely in granular crystals. Its specific gravity, is 1·386. It melts at 212°, and at 286°, changes into caromel [163]. Strong mineral acids, which hardly act upon cane sugar, decompose grape sugar. Oil of vitriol dissolves it, and produces *sulpho-saccharic acid*, which, as sulpho-saccharate of lead ($2C_{12}H_{11}O_{11}+SO_3+4PbO$), is not precipitated by barytes.

169. Alkalies, which form compounds with cane sugar, decompose grape sugar. Lime, which affects cane sugar but slowly, forms very rapidly, with grape sugar, *glucic acid* ($C_{12}H_8O_8$)—in its dry state, isomeric with *lignine*. When a solution of caustic potash is boiled with grape

* *Gluhũs*, sweet. Gr.

sugar, the resulting *glucic acid* is decomposed: and a brown liquor is formed, which, with hydrochloric acid, affords *mellassic** *acid* ($C_{24}H_{12}O_{10}$), in the form of a black flocculent precipitate. Cane sugar rotates the plane of polarization [opt. 212] to the left: but grape sugar, almost always, to the right.

170. Beet-root is used for the manufacture of sugar. It was first employed, for that purpose, by Napoleon: with the intention of rendering France independent of England. It is probable that this manufacture, which has already succeeded extremely well in this country, will be hereafter found greatly to increase the sources of its wealth.

171. LACTINE† or "sugar of milk:"—$C_{24}H_{19}O_{19}+5Aq$, when crystallized. It has been found, as yet, only in the milk of the mammalia: and may be obtained, by evaporating whey to a pellicle. On setting it aside to cool, the sugar crystallizes: and the crystals may be purified, with animal charcoal, and repeated crystallization. They are white, semitransparent, hard, and crackle under the teeth. Their specific gravity is 1·543. They are insoluble in alcohol, or ether: but dissolve in six parts of cold, and in two and a half of boiling water: and their solubility is increased by the presence of an acid, or an alkali. Their concentrated solution does not form a syrup [163]. They are but slightly sweet; and rather less so than their solution. Heated at 290°, they give off two atoms of water: at 300°, they fuse, and abandon three atoms more. Sugar of milk is changed into grape sugar, by digestion with dilute sulphuric acid. Like gum, and unlike the other sugars, it forms *mucic acid* [159], when acted upon with nitric acid.

172. The following, according to Liebig, are the constituents of starch, gum, and the sugars which we have noticed:—

Starch	$=(C_{12}+10HO)$
Gum	$=(C_{12}+10HO)+HO$
Cane sugar	$=(C_{12}+10HO)+HO$
Sugar of milk	$=(C_{12}+10HO)+2HO$
Grape sugar	$=(C_{12}+10HO)+4HO$

173. MANNITE:—$C_6H_7O_6$. It is the sweet principle of "manna;" and—though it does not form alcohol [162]—is

* *Melas*, black. Gr. † Lac, milk. Lat.

closely connected with the sugars. It is generated, along with other substances, when beet-root, or carrot, is kept for some time at the temperature of 100°—what has been called the *mucous fermentation* being produced. This species of fermentation, which sometimes causes loss during the manufacture of sugar, may be produced by contact with "mucous membrane."

174. DIASTASE,* is that principle in malt, which converts starch into sugar. It contains nitrogen; but its constitution has not yet been determined.

It may be obtained, by moistening malt, of the best kind, with water: then pressing it, and mixing the juice with a little alcohol—to separate the albumen, &c.: lastly, filtering, and evaporating to dryness. The residue, a white gummy mass, is impure diastase.

175. It is tasteless, and without colour. It is soluble in water, and weak alcohol: but insoluble, in absolute alcohol. If the temperature does not exceed 158°, one part diastase will, in a few hours, change 2,000 parts starch into sugar: and as the change proceeds, will itself disappear: but a boiling temperature destroys its power of forming sugar. It is precipitated by infusion of galls, and by most metallic salts. The presence of diastase, during fermentation, changes the starch of the seed into sugar.

176. THE VINOUS FERMENTATION.—Fermentation is divided into the *saccharine*,† in which starch is changed into sugar; the *vinous*,‡ in which sugar is changed into alcohol; the *acetous*,§ in which the alcohol is changed into acetic acid; the *viscous* or "mucilaginous,"‖ in which gum is one of the products—it occurs, when malt liquor is fermented without yeast; and the *putrefactive*, in which the whole substance undergoes decomposition—the results being a number of new products, accompanied by a disagreeable smell. Other processes are, occasionally, termed fermentation:—thus, the *lactic*,¶ in which sugar is changed into lactic acid; and the *panary*,** which occurs during the fermentation of dough, but which is resolvable into one of

* *Diastēmi*, I separate. *Gr.*
† *Saccharum*, sugar. *Lat.*
‡ *Vinum*, wine. *Lat.*
§ *Acētum*, vinegar. *Lat.*
‖ On account of the formation of mucus.
¶ *Lac*, milk. *Lat.*
** Panis, bread. Lat.

the others—generally the vinous. The lactic fermentation, requires only starchy, or saccharine matters, and not alcohol: and when once begun, does not need the presence of atmospheric air. The panary is not a distinct fermentation; since if the sugar be removed from flour, the latter will not ferment of itself, so as to form leaven.

177. *The vinous fermentation* takes place when saccharine solutions, at a proper temperature, are placed in contact with substances in a state of decomposition—*yeast*, for instance. Blood, white of eggs, glue, flesh, &c., if they have begun to putrefy, would also cause sugar to ferment. During fermentation, new compounds are produced; and the liquor will afterwards be found to contain *alcohol*.

178. Substances which have no nitrogen are, of themselves, incapable of the vinous fermentation; but they are made to ferment, by the addition of a substance containing it. Sometimes, the liquid to be fermented contains the *ferment* or exciting body within itself:—thus, the juice of the grape. The nitrogenised substances of the fermenting liquor, are precipitated as "ferment:" and may be used to cause, or to commence, the fermentation of other liquors.

179. Contact with the atmosphere is necessary to begin, but not to continue, the vinous fermentation. The skin of fruits, while entire, prevents fermentation, by excluding the air. During the formation of alcohol, one atom of grape sugar ($C_{12}H_{11}O_{11}+HO$, when dried at 212°), produces four atoms of carbonic acid, and two of alcohol ($C_4H_6O_2$). $(C_{12}H_{11}O_{11}+HO)=4CO_2+2C_4H_6O_2$. Every kind of sugar, before fermenting, is changed into grape sugar. The various species of sugar, do not all ferment with equal facility. Milk requires a strong ferment, and an acid, to change sugar of milk into grape sugar: hence, it does not ferment, until it has become sour, and coagulated.

180. BREWING.—The method of producing fermented liquors, appears to have been known from the earliest times: but distillation, not until a comparatively recent period. It seems to have been known, from the earliest times, that barley is the best grain for beer. We are told, by Herodotus, that the Egyptians made a wine from that *substance*: having no grapes. The Greeks called their *beer* "barley wine." And we are informed, by Tacitus,

that beer was the favourite drink of the ancient Germans: as it still continues to be of the modern. The first and most important step, preparatory to brewing, is "malting" the corn—which, by means of incipient germination [167], changes the starch into sugar. For this purpose, the grain is steeped in soft cold water, for about sixty hours: after which, the water being drained off, its temperature rises: and it begins to grow—but the growth is stopped, by the heat of a kiln. All the starch has not been transformed into sugar:—if it were, the entire grain, except the husk, would now be perfectly soluble. Too high a temperature, in the kiln, would injure the saccharine matter, which—at least when separated from the malt—is decomposed below the boiling point of water.

181. After the malt has been ground, it is "mashed," with water not sufficiently hot to form the starch which remains, into paste. And, as the undecomposed starch is gradually changed, by its own gluten, into sugar, water of gradually increased temperature is added. Mashing renders the solution of the saccharine matter complete. The clear liquor or "worts," is next strained off: and is immediately transmitted to the coppers, to be partially boiled away, and further clarified. Boiling with excess of oxygen, would throw down vegetable matter, as an insoluble precipitate: which would be a source of waste.

182. With proper management, the same kind of wort can be obtained from one part malt and eight parts barley, as from nine parts malt. The solid ingredients of beer wort are sugar, and dextrine, with a little vegetable albumen. If sugar alone were present, the fermentation could not be stopped, at ordinary temperatures, until nothing would be present but alcohol and water, or vinegar—formed by the absorption of oxygen. But, since dextrine ferments with difficulty, and but slowly, carbonic acid may be evolved for years after the sugar is gone; and thus the beer may remain brisk while, at the same time, acetification does not occur, since oxygen is excluded. The longer, therefore, the beer is to be kept, the greater the amount of dextrine it ought to contain. The whole of the dextrine may be precipitated from strong wort, as a dense coagulum, by *adding an equal* volume of strong alcohol: if the wort

is weak, more alcohol will be required. The dextrine is gradually changed into sugar, by keeping up the temperature of the mash-tun, and prolonging the mashing; or keeping the wort at 170° Fahr. for a proper time.

183. Hops are next added. They were first imported from the Netherlands, about the year 1524. Most of their useful properties reside in a fine yellow powder, which may be separated from them. They contain a volatile oil, also, which gives an agreeable aroma to the beer: but most of it is driven off, by the temperature at which the wort is boiled. The hop changes the flavour of the beer, adds to its narcotic qualities, and prevents acetous fermentation.

184. After the bitter principle has been extracted from the hops, the liquor is strained into a vessel called a "cooler." It must be cooled rapidly, to prevent acidity. When it is cooled, it is transferred to the "fermenting tun," and yeast is mixed with it. Carbonic acid now escapes, in large quantities, through the viscid froth, which forms on the surface, and which is ultimately removed.

185. To clear the liquor from the yeast which, if allowed to remain, would produce acidity, and to check the vinous fermentation, it is poured into lesser vessels:—the small quantity of saccharine matter, which is thus left undecomposed, afterwards generates carbonic acid, in the beer, &c. The liquor may be still further cleared, by "fining:" which is effected by adding isinglass dissolved in sour beer. Becoming entangled in the particles which produce turbidity, it falls along with them, to the bottom of the vessel. Other substances might be used, for the same purpose.

186. In making beer, mashing not only dissolves the sugar and gum already in the malt, but also converts the starch, which is not changed during germination, into a sweet mucilage. Starch mixed with gluten, and digested for some time with hot water, becomes a kind of sugar. If the sweet mucilage obtained by mashing, and which probably consists of gum liquid starch and sugar, is kept for 20 or 30 minutes at a temperature between 158° and 167°, the pasty solution becomes perfectly fluid; and, being evaporated after having been suddenly raised to the boiling point, a substance is obtained, which answers for many of

the purposes to which gum is applied. But, if it is kept between 158° and 167° for three or four hours, most of the gum will under the influence of diastase become sugar.

In the manufacture of *Bavarian beer*, the fermentation is kept at a temperature not sufficiently low to acetify the alcohol; and the separation of the azotized matters, is effected by the intervention of the oxygen of the air, and not by sacrificing any of the sugar.

187. The presence of alcohol, in beer, &c., may be shown, by means of dry carbonate of potash—which is insoluble in alcohol. It will be dissolved by the water, contained in the liquor, and the alcohol will float over the solution.

188. DISTILLATION.—The changes which occur, during the process of brewing, have produced alcohol; but its formation is not the sole object of the brewer:—it would not even suit his purpose to generate so much of it, as he might have done. The ends proposed by the distiller, are quite of another kind. He, also, produces alcohol by fermentation, but he *separates* it from the fermented liquor. Hence, his mode of obtaining it must be somewhat different from that which we have just described—though founded on precisely the same principles.

189. As the alcohol is to be removed from the substances with which it is associated, and the qualities of the residue are of but little consequence to him, it is not necessary for the distiller to provide against acetification. Also, in distillation, as much alcohol as possible is formed. The ingredients used are not, necessarily, grain; and, if grain, it is not required to be of the same kind, nor that the entire—nor, indeed, any of it—should be malted: it is even said that malting diminishes the amount of alcohol. The large quantities of yeast, which are employed, produce a very energetic fermentation, which is quite sufficient, of itself, both to form, and separate the sugar. The fermented liquor is, in distillation, termed "wash."

190. The wash is transferred to the *still*, a boiler so contrived, that the vapour, which arises from it, is conveyed, by a bent tube, called the *worm*, through cold water: and is thus condensed into a liquid. Those fluids *which boil at a lower* temperature than water—such as

alcohol, and the essential oils—rise first, by evaporation; but, since bodies communicate to others the capability of being evaporated, at low temperatures [inorg. chem. 338], they carry along with them a portion of the water, in the form of steam. The mixture of alcohol and water, which condenses in the worm, is transmitted to a suitable vessel. A second, third, and fourth distillation, will strengthen the alcohol, by removing successive portions of the water, with which it is diluted: but a fifth, is productive of no further effect. The vapour of water condenses, chiefly, in the first, or hotter parts of the worm: contrivances have, therefore, been employed, for conveying it back to the still, instead of allowing it to pass into the receiver. The first distillation gives what is, technically, termed "singlings;" the second, at the commencement, "first shot;" and afterwards "whiskey;" subsequent distillations "rectify," by removing water, and a very disagreeable essential oil. The latter, causes the bad flavour of inferior spirits: and is often present in such quantity as to produce turbidity, when the alcohol is rendered so dilute, by the addition of water, as to be no longer capable of holding it in solution.

191. ALCOHOL:—$C_4H_6O_2$, when anhydrous. It may be considered as *etherine* (C_4H_4), combined with two atoms of water. Spirits may be obtained, from any of the vast number of substances, which contain starch, or sugar; but their qualities are different—particularly their flavours, which are due to the essential oils they hold in solution, and which may be separated from them. The residue, after this oil, and every other impurity, has been removed, is termed *alcohol;* and, from whatever source it may have been derived, it is always the same.

192. According to Brande, ordinary spirits, such as brandy, whiskey, &c., contain from 40 to 50 per cent. and upwards, alcohol. Strong wines, such as port or sherry, from 19 to 25 per cent. The wines of France and Germany, about 12 per cent. Strong ale about 10 per cent. The specific gravity of *proof spirit*—which contains 48 per cent. alcohol—is about 0·920. The most highly rectified spirit, contains only 90 per cent.: and its specific gravity is between 0·835 and 0·840, at a temperature of

60°. This is the greatest strength, attainable, by simple distillation. If a purer alcohol is required, some substance —such as pearl-ash, &c.—that has an affinity for water, must be distilled along with it, from a water bath :—part of the pearl-ash will, however, pass over, also [inorg. chem. 338].

193. If it is not necessary that it should contain more than 98 per cent. absolute alcohol, it may be obtained of that strength, by tying it up in a bladder. The water which exceeds 2 per cent., will pass through the membrane, and will be evaporated from its surface [inorg. chem. 212]: —but some of the alcohol, also, will pass off from the empty portion of the bladder.

194. Alcohol, made from damaged grain, contains a fetid volatile fatty matter; and intoxicates more easily than good spirit, sometimes even causing phrensy. This is more or less effectually removed, by various means. *Fusil oil*, the oil contained in bad or imperfectly purified spirit, is highly poisonous: it evaporates at a lower temperature than water. Corn spirit contains, likewise, an offensive fatty matter.

195. *Absolute alcohol*, or that which is perfectly anhydrous, may be obtained, by saturating fused chloride of calcium with the most highly rectified spirit: and distilling from a water bath. Or, by pouring very strong alcohol upon quick-lime. The water of the alcohol will slake the latter; and so much heat will be produced, as will cause absolute alcohol to pass over, in vapour.

196. Absolute alcohol, is a clear and colourless fluid. Its specific gravity at 60°, is 0·7947. It is a non-conductor of electricity. It boils at 168°: and has never yet been frozen. Since its boiling point is the same as that of alcohol containing 6 per cent. water, the first part of what is obtained, by distillation, from fused chloride of calcium [195] should be rejected, as hydrated. Alcohol has a strong affinity for water :—which makes it be destructive to life, on account of its depriving the organs of the water required by them. The same reason causes it, even when dilute, to produce a burning sensation in the mouth and throat. When it combines with water, condensation occurs, and heat is evolved. If one atom of alcohol is added

to six of water, the bulk of the mixture will be to that of its constitutents, as 100 is to 103·735.

197. An alcohometer, or instrument for measuring the amount of alcohol in a fluid, has been constructed on the principle, that the boiling point of a fluid containing alcohol depends on the relative quantity of the latter, even if a moderate quantity of saline, saccharine, or extractive matter, is present. If, however, so much dry carbonate of potash or sugar is added to the fluid, as will reduce to the solid state, a portion of the water present, the boiling point will be lowered, in proportion to the concentration produced in the alcohol. This instrument detects the amount of alcohol in wines, &c. When the quantities of spirit in the fluid are relatively very great, the boiling points vary so little that, before examining it, the fluid is conveniently diluted with an equal bulk of water, and the necessary allowance is then made.

198. Snow and absolute alcohol constitute a very effective freezing mixture [heat 114]:—the alcohol, on account of its affinity for water, melts the snow with great rapidity.

199. If alcohol is rendered impure, by the presence of an essential oil, it will be discoloured by colourless oil of vitriol; or by nitrate of silver and exposure to the sun's rays. It should produce no change, in test paper; and, when evaporated, should leave no stain.

200. Alcohol is decomposed, by oxacids, into water, and the oxide of *ethyle* (C_4H_5O) or *ether*—which generally remains in combination with the acid. Thus, nitric acid (containing no nitrous acid) and alcohol, form nitrate of the oxide of ethyle, and water. $NO_5+C_4H_6O_2=(NO_5+C_4H_5O)+HO$. Hydracids decompose the oxide of ethyle, and, at the same time, themselves suffer decomposition. Thus, hydrochloric acid (in the nascent state) and alcohol, form chloride of ethyle, and water. $HCl+C_4H_6O_2=(CH_5Cl)+2HO$.

201. An alcohol, taken in the more extended sense, is considered to be, "a substance which may be represented by two atoms of water and a hydrocarbon isomeric with olefiant gas; which, being deprived of an atom of water, forms an ether; and which, the two atoms of water being replaced by four atoms of oxygen, forms an hydrated acid."

These conditions apply to others, besides the ordinary or vinous alcohol. Thus—

Alcohol.

Wood alcohol.	Vinous alcohol.	Oil of potato spirit.	Ethal.
C_2H_2+2HO	C_4H_4+2HO	$C_{10}H_{10}+2HO$	$C_{32}H_{32}+2HO$

Ether.

C_2H_2+HO	C_4H_4+HO	$C_{10}H_{10}+HO$	$C_{32}H_{32}+HO$

Acid.

$C_2H_2+O_4$	$C_4H_4+O_4$	$C_{10}H_{10}+O_4$	$C_{32}H_{32}+O_4$

Only vinous alcohol, and the substances connected with it, are of sufficient importance to require notice here.

202. ETHER.—An ether is a very volatile fluid, produced by the distillation of alcohol with an acid. We shall confine ourselves to *sulphuric ether* (C_4H_5O), called more commonly *ether*. It may be obtained, by adding potassium to absolute alcohol:—potash and ether will be formed, and hydrogen will be evolved. It is, however, very conveniently procured, by mixing equal weights of rectified spirit and oil of vitriol. Any considerable rise of temperature must be avoided: distillation ought to be effected, not in an open fire, but a sand bath: and the greatest care should be taken, throughout the whole process, on account of the inflammable nature of both alcohol, and ether. A mixture of ether alcohol and water, will pass over. The first product is a fragrant spirit; then, as soon as the liquid boils, ether; next, a light yellow oil, called "sweet oil of wine;" finally, sulphurous acid, and olefiant gas—after which, the mixture becomes thick and black, and froths up. It is very economical to add the alcohol by degrees—if possible in a continuous stream. This may be done, by means of a safety funnel [inorg. chem. 86]. The reactions we have mentioned, are then avoided; and the same oil of vitriol, will decompose twice its weight of rectified spirit. Ether continues to be set free, until the sulphuric acid becomes so weak as to be quite ineffective: that is, until it is SO_3+4HO, which, unless at a high temperature, is incapable of decomposing alcohol.

203. This process is not so simple as might be imagined. The sulphate of ether ($SO_3+C_4H_5O$), which is first produced, combining with another atom of oil of vitriol, forms

bisulphate $[(SO_3+C_4H_5O)+(SO_3+HO)]$ or *sulphovinic acid*—which affords a soluble salt with barytes, or oxide of lead. It is then decomposed, by the excess of water present: and, in this point, resembles the sesquioxides of iron, bismuth, and antimony, which, if combined with sulphuric acid, are set free by water—particularly when it is at a boiling temperature.

204. If the heat is kept moderate, during the process, scarcely any water passes over along with the ether. The latter is rendered perfectly pure, by rectification with dry carbonate of potash from a water bath.

205. Ether is a colourless liquid, of a penetrating, but agreeable smell, and a pungent taste. Its specific gravity at 60°, is 0·720. It is a non-conductor of electricity. It crystallizes at—47°: and boils in the atmosphere at 96°, but in vacuo at—44°. It evaporates, at ordinary temperatures, with great rapidity, causing considerable cold [heat 90]. Its vapour, like that of alcohol, when mixed with common air, is explosive; and it is so volatile, that it is dangerous to take the stopper out of a vessel containing it, near a candle. It dissolves, in ten times its weight of water:—but alcohol is slowly produced, by the ether combining with that fluid. This combination takes place rapidly, if the ether is in the nascent state:—as, when the acid salts of ethyle are heated with water; or, when its neutral, or haloid, salts are decomposed, by being heated with hydrated alkalies; or when, during the vinous fermention, sugar is decomposed.

206. If a small quantity of ether is thrown into a bottle of chlorine, a white vapour is produced, with explosion and flame. Ether dissolves iodine, and bromine, abundantly; but they ultimately act upon it. If the salts, which ether forms with acids, have an acid reaction, they are termed *acids*—thus, phosphovinic acid $(PO_5+C_4H_5O+2HO)$; if they are neutral, *compound ethers*—thus oxalic ether $(C_2O_3+C_4H_5O)$.

207. Ether has been considered, by some, to be a combination of olefiant gas and water—or its elements; and, by others, the oxide of an hypothetical radical *ethyle* (C_4H_5, or *Ae*). This difference of opinion, is similar to *that which* exists regarding the nature of ammonia:—the

ɔn being, whether the oxygen and hydrogen present
ı, actually constitute water, or form an integral part
ıase. If *acetyle* (C_4H_3, or *Ac*) is supposed to be
dical of ether, and *amidogene* (NH_2, or *Ad*)—as
ed by Sir R. Kane—that of ammonia, their com-
s will agree in a very remarkable manner—

le, . . .	*Ac*	Amidogene, . .	*Ad*
nt gas, . .	AcH	Ammonia, . .	*Ad*H
e, . . .	AcH_2	Ammonium, . .	AdH_2
, . . .	AcH_2O	Oxide of ammonium,	AdH_2O
ide of ethyle, .	AcH_2Cl	Sal-ammoniac, .	AdH_2Cl

. The following is a tabular view of the most inter-
substances connected with alcohol—

t gas or elayle, . .	C_2H_2
l, etherine, or light oil of	
;	C_4H_4
, ...	*Ae*; or C_4H_5
of ethyle or ether, .	*Ae*O
of ethyle and water, or al-	
l, ...	*Ae*O+HO
le of ethyle or hydrochloric	
r, ...	*Ae*Cl
of ethyle or hydriodic ether,	*Ae*I
le of ethyle or hydrobro-	
ether, ...	*Ae*Br
ret of ethyle or hydrosul-	
ic ether, ...	*Ae*S
huret of ethyle or thialol, .	AeS_2
r alcohol or mercaptan, .	*Ae*S+HS
le of ethyle or hydrocyanic	
r, ...	*Ae*Cy
vinic acid, . . .	[(SO_3+*Ae*O)+(SO_3+HO)]
ovinic acid, . . .	(PO_5+*Ae*O)+2HO
ovinic acid, . . .	(AsO_5+*Ae*O)+2HO
ate of the oxide of ethyle or	
nic ether, . . .	CO_2+*Ae*O
oxycarbonic ether, . .	[(CO_2+*Ae*O)+(COCl)]
inic acid, ...	[(CO_2+*Ae*O)+(CO_2+HO)]
carbonic ether or hydrox-	
ic acid, ...	[(CS_2+*Ae*O)+(CS_2+HO)]
e of oxide of ethyle or ox-	
ether, ...	C_2O_3+*Ae*O
inic ether, . . .	[(C_2O_3+*Ae*O)+(C_2O_3+HO)]
than or oxalate of the ox-	
f ethyle and oxamide, .	[(C_2O_3+*Ae*O)+(C_2O_3+*Ad*)]
e of the oxide of ethyle or	
c ether, ...	$\overline{A}$+*Ae*O

1,000 lbs. of whole grain contribute to the matter
the muscles . . . . .
,, fine flour ,, ,, ,,
1,000 lbs. of whole grain contribute to the formation
bone and saline matter . .
,, fine flour ,, ,, ,,
,, bran ,, ,, ,,

Fortunately for themselves, workpeople are de
the finer kinds of bread.

213. LIGNINE :—$C_{12}H_9O_8$. It is formed from
[11] three atoms of water being removed. It c
the tubes, and cells, of vegetable tissues: and m
tained, by successive and repeated treatment of w
dilute acids, alkalies, water, and alcohol—to take
the soluble substances. It is quite white, when
remains undecomposed for a long time, if kept eit
dry, or under water—which protects it from oxy
is changed, by hot nitric acid, into oxalic acid
sulphuric acid, first into gum, then, boiled with w
grape sugar. Sawdust, treated for some hour
warm solution of potash, gives a mixture of st
lignine, which, with iodine, will strike a blue col
bleaching of linen, frees the lignine from resi
other matters associated with it. As flax, when
consists almost entirely of lignine, if what has b
rated from it is returned to the soil, it will no lon
exhausting crop.

214. GUN COTTON.—Braconnot observed, in 1
when starch was heated in strong nitric acid, u
plete solution took place, if the solution was pou
large quantity of cold water, a white pulverule
phous mass gradually subsided, and, on being d
highly combustible—burning without any residu
substance was called "Xylodine:"* and consist
ing to Pettenkofer, of $C_{36\cdot76}H_{4\cdot79}O_{32\cdot80}N_{5\cdot65}$; but
to others, of $C_{12}H_9O_{10}N_2$. Pelouze, in 1838, rep
experiments of Braconnot, and ascertained th
linen, cotton, and other ligneous substances, with
ing their appearance, gave apparently the same
being submitted for a few moments to the action

* Xulon, wood. Gr.

acid, specific gravity 1·5, they were well washed with water, and dried: and he suggested its application, as a substitute for gunpowder. But he, and other chemists, have since found that, what are obtained from starch, and from woody fibre, are not identical. The latter has been called *pyroxyline*, or "pyroxyle:"—and, according to Pelouse, consists of $C_{26\cdot66}H_{3\cdot70}O_{29\cdot28}N_{10\cdot36}$.

215. *The gun cotton* of Schönbein, is one form of this substance. It is prepared, by immersing clean cotton, for about fifteen minutes, in a mixture consisting of equal parts concentrated nitric and sulphuric acids—none of the cotton being left above the liquid, lest an accident should occur. The acid being pressed out, the cotton is washed with water, until it ceases to redden litmus paper: and is then dried, at a temperature not exceeding 212°, a free current of air being made to pass over it. The formation of lumps, which are highly explosive, must, as much as possible, be prevented. The sulphuric acid takes a hold of the water of the nitric acid—perhaps that which is separated from the constituents of the cotton. Gun cotton may be prepared, for the purpose of photography [opt. 123], by mixing together with a glass rod, half an ounce of dried nitrate of potash, and three quarters of an ounce of sulphuric acid, spec. grav. 1·85: then stirring rapidly in the mixture, for a few moments, half a drachm of clean, dry cotton, removing the cotton, washing it well with water, and drying it at moderate temperature. Cotton wool, according to Pettenkofer, consists of $C_{44\cdot5}H_{6\cdot1}C_{49\cdot4}$; and gun cotton, according to Schönbein and Böttinger, of $C_{27\cdot43}H_{3\cdot54}O_{54\cdot77}N_{14\cdot26}$. The latter is thought by some, to consist of an atom of cotton, and two atoms of nitric acid, minus two atoms of hydrogen. $C_{12}H_{10}O_{10}+2NO_5-2H=C_{12}H_8O_{20}N_2$.

216. Gun cotton explodes by percussion, but not by friction. It takes fire at the temperature of 356°, which is less than that required by gunpowder: and hence, it may be exploded, on gunpowder, without ignition being communicated to the latter—indeed it has sometimes ignited, at less than 212°. Its explosion produces carbonic oxide, carbonic acid, cyanogen, nitrogen, nitric oxide, and water—without any residue; and is accompanied by very *little smoke*. Its force is four times as great, as that

of gunpowder; and, hence, it is highly efficient in blasting rocks. But it ignites so rapidly, and is so very hygrometric, that it is not likely to be much used, in war. Its effect is greatly increased, by impregnating it with chloride of potash—which, also, prevents the trifling injury that it does to fire-arms. It is insoluble in water; but may be purified, by solution in acetic ether. When dissolved [eqn. 128], it is named *collodion*.* Gun cotton differs from xyloidine, in not being affected by acids.

217. EXTRACTIVE MATTER.—If a vegetable juice is evaporated, by a gentle heat, the oxygen of the air, acting upon it, forms a brownish black precipitate:—this is "extractive matter." It is sparingly soluble in water; but is easily dissolved by alkalies. It is very similar to the substance, which is produced by the action of the atmosphere, on animal, and vegetable bodies.

218. GLUTEN is the residue of wheaten flour, after the starch has been washed away. It may be obtained, by washing wheaten flour, in a linen bag, as long as any thing is removed: and treating what remains with boiling alcohol:—when water is added, and the alcohol is distilled off, the gluten is deposited in large coherent flakes. Boiling with water, dissolves out the *mucin* from the gluten.

219. Gluten contains nitrogen. It is of a pale yellow colour: and, when soft, is elastic. It is soluble in acetic acid, and alkalies: and is precipitated, in combination with oxides, by earthy, or metallic salts. It gives a slightly soluble precipitate, with sulphuric acid.

220. VEGETABLE ALBUMEN† is the residue, when the gluten has been dissolved out [218] by boiling alcohol. It contains nitrogen. Unlike gluten, it is not elastic when soft. To a certain extent, it is soluble in water: and the solution is coagulated by heat. It dissolves in alkalies, and is precipitated by earthy salts, and by the acids—except the phosphoric, and acetic. Wood is preserved from decomposition, by combining the albumen present, in its juices with a metallic salt.

221. LEGUMINE is obtained by diffusing powdered peas through water: then pouring off, and evaporating the

* *Kolla*, glue. Gr.: from its appearance.
† *Albumen*, white of egg. Lat.

fluid:—the legumine rises to the surface, in transparent pellicles. It contains nitrogen, and sulphur. It is soluble, in vegetable, and is precipitated, by mineral acids. It is dissolved by alkalies: and is thrown down again by earthy, and metallic salts. Its solution is not coagulated by heat.

222. FIBRINE.—It consists of $C_{800}H_{620}O_{240}N_{100} + PS_2$, with small quantities of lime, and magnesia. It is the chief constituent of muscular fibre; and is a very important element of the blood—being contained by that fluid in solution, until it coagulates. It is procured, by agitating fresh drawn blood, with a bundle of twigs: then washing what adheres to the twigs—to remove the colouring matter: and digesting it in alcohol, or ether—to take away traces of fat. When dried, it is without colour, taste, or smell:—unless fat is present, it is not transparent. It absorbs water, so as to recover its softness and flexibility. With oil of vitriol, as also with monobasic and bibasic phosphoric acid, it forms a yellow transparent jelly. The latter is a compound of fibrine and the acid: and is soluble in water, when the excess of acid is washed away:—water being added, it becomes hard. Fibrine, acted upon by nitric acid, forms *xanthoproteic* acid ($C_{34}H_{25}O_{12}N_4$), a yellow powder. Strong hydrochloric acid causes it, when quite dry, to swell up, and then dissolves it:—the solution is a dark blue liquid, which gives a precipitate with ferrocyanide of potassium. It is soluble in tribasic phosphoric, and in acetic acid: and the solutions are precipitated, by mineral acids, and by caustic potash—the precipitate, formed by the latter, being soluble in excess. A solution of fibrine, in dilute caustic potash, is almost neutral. It is coagulated by alcohol, and acids: but not by heat. Dissolved in a solution of saltpetre, it is coagulated by heat, alcohol, and acids: and is precipitated by ferrocyanide of potassium, and the salts of mercury, lead, and copper. There is a great resemblance between fibrine and gluten [218].

223. ANIMAL ALBUMEN.—Its constitution is $C_{800}H_{620}O_{240}N_{100} + PS_4$—along with more lime, &c., than fibrine. Albumen is found in the white of eggs, serum of the blood, fluid of dropsy, &c. It assumes both a soluble, and an insoluble form.

Soluble albumen is obtained by evaporating to dryness, either white of egg, torn up by triturition with fragments of glass, or serum of the blood, at a temperature not higher than 120°. The result, being digested in alcohol, or ether, will be pure albumen; and without colour, taste, or smell. At first, it swells up, and then dissolves in cold water: and the solution coagulates between 140° and 150°. If dilute, it does not coagulate at a temperature lower than 165°—nor, if the quantity of albumen is very small, below 212°. It is coagulated by tannic, and other acids—except acetic: and by minute quantities of creosote. Once coagulated, it is insoluble. If quite dry, it may be heated to 212°, without losing its solubility. In solution it is thrown down by alcohol, acids, and metallic salts:—when the precipitate is formed by the latter, it consists of albumen combined with the acid, and albumen combined with the oxide.

224. *Coagulated albumen* is procured by coagulating serum of the blood with hydrochloric acid, washing the coagulated mass with acidulated water, dissolving it in water, and decomposing the solution with carbonate of ammonia—which separates the albumen, as a white flocculent substance. It is yellow, and transparent, when dry: and very much resembles fibrine, in its properties, &c. It is not soluble in water, but dissolves in caustic alkali.

225. Albumen is kept in the liquid state, in white of eggs, by the presence of soda. Unless coagulated, it putrefies rapidly, if exposed to the air. In the state of concentration, in which it is found in the serum of the blood, it dissolves some metallic oxides—particularly protoxide of iron. It is therefore, the solvent of the iron, which [inorg. chem. 173] performs so important a function, in respiration. Seven or eight parts hydrochloric acid, and one of coagulated albumen, strike an intense blue colour —particularly if heated to 80°. Corrosive sublimate is a most delicate test for albumen; and detects it, when dissolved in 2,000 parts water. It is [inorg. chem. 576] an antidote for corrosive sublimate: and, also, for the salts of copper—forming with them a white, and harmless precipitate. Albumen clarifies a liquid: for, heat being applied, it coagulates, and, entangling with the substances

that render the fluid turbid, all are removed together. Wine, &c., may be clarified by albumen, without heat: since the tannin they contain, forms with it an insoluble compound:—and the effect of coagulation is thus produced. Animal, and vegetable albumen, are, in all respects, very similar.

226. CASEINE:*—$C_{400}H_{310}O_{120}N_{80}+S$, with two atoms bibasic phosphate of lime. It is one of the constituents of cheese: and may be obtained, by adding sulphuric acid to skimmed milk. The caseine is precipitated, in combination with the acid: and, being washed with water, is digested with carbonate of barytes. The resulting solution of caseine in water, is filtered, and alcohol is added—to throw drown the caseine. The latter is purified, by digesting with ether—to remove any trace of butter.

227. Caseine dissolves in water, forming a thick mucilage, having the smell of boiled milk. It dries into a thick amber-coloured mass, without losing its solubility. Its solution is coagulated by alcohol, and acids. When coagulated by *rennet*, it cannot be distinguished from coagulated albumen.

228. It is thought that caseine consists of *tyrosine* ($C_{16}H_9O_5N$), and *leucine* ($C_{12}H_{12}O_4N$). The former, may be obtained by fusing caseine with caustic potash: then dissolving the residue in water, and adding acetic acid to the solution. Tyrosine separates, in the form of brilliant needles; and leucine may be obtained, from the mother liquor, by evaporation. Caseine seems identical with legumine [221].

229. It has been supposed, by Mülder, that fibrine, albumen, and caseine, with the corresponding vegetable elements, are, compounds of sulphuret of phosphorus, and a substance, named by him *protein* ($C_{40}H_{31}O_{12}N_5$). The latter, may be obtained by digesting fibrine, or albumen, in water, alcohol, and ether—to remove all substances which are soluble: then in dilute hydrochloric acid, to take away the earthy salts: dissolving the residue in caustic potash, and heating the solution to 120°—to form phosphate of potash, and sulphuret of potassium, with the phosphorus and sulphur: and, finally, precipitating the pro-

* *Caseum*, cheese. *Lat.*

tein, with acetic acid—which, as it would re-dissolve the precipitate, is not to be added in excess. The resulting greyish white gelatinous flocks, according to Mülder, form, when dried, an amber-coloured powder, which by absorbing water, regains the appearance it had, before exsiccation. There are probable reasons against Mülder's opinion.

230. From the great resemblance, if not identity, of the most important vegetable, and animal substances, it follows that, in reality, the same principles constitute the food of both graminivorous, and carnivorous animals. Where the vegetable ends, the animal begins: and thus proceed the formation of numerous and complicated compounds. There are, in the vegetable, and animal kingdoms, many corresponding bodies, besides those to which we have directed attention. The fat of beef, and mutton, is present in cocoa beans; human fat, in olive oil; the principal ingredients of butter, in palm oil: horse fat, and train oil, in certain seeds, &c.

231. Vegetable Jelly or *pectin** :—$C_{24}H_{17}O_{22}$. It is found in almost all parts of every kind of plant: and may be obtained, by filtering the expressed juice of beet, celery, currants, &c., and mixing it with alcohol. After some hours, the pectin will separate, as a jelly: and, being washed with alcohol, must be dried with a moderate heat. It is without colour, taste, or smell; and forms a jelly with 100 parts water. It gives precipitates, with salts of barytes, copper, lead, and peroxide of iron. It is changed, by boiling with strong acids, or bases, into *pectic acid*—isomeric with pectin. When the latter, or pectic acid, is boiled with an excess of potash, until the liquid ceases to give a precipitate with hydrochloric acid, *metapectic acid*, which is penta-basic—and is, also, isomeric with pectin—is produced.

232. Gelatine. Its constitution, according to Mülder, is $C_{18}H_{10}O_5N_2$. It does not—as might at first be supposed, on account of the resemblance between vegetable and animal albumen, &c. [230]—at all correspond with vegetable jelly. It exists in the skin, cartilages, tendons, membranes, &c. Gelatine gives toughness to bones, and the salts of lime, strength. Half the bones of an ox, are gela-

* *Pēktis*, coagulum. Gr.

e. It is very abundant, in the bones of young animals: ich, therefore, are the less easily fractured. Fish bones, wever, are weak, from containing excess of gelatine. If nes are digested in very dilute hydrochloric acid, carnic acid will be given off, on account of the carbonate of ne present [inorg. chem. 464]: and, after some days, e salts being dissolved out, a semi-transparent mass, of e same form as the original bone, will remain. It is xible, and somewhat elastic: part of it is soluble in boilg water. This is gelatine, and will be glue, on cooling. he remainder becomes hard, and brittle, in drying, and rns like horn:—this is albumen, or membrane [223]; d is soluble in caustic alkali. Fat is generally present bone; but the horn of the stag, being free from it, jelly, ade by boiling harts' horn shavings, is often given to perns of weak digestion. Gelatine is found abundantly in mmerce. It is obtained in an impure state, as common *ue*, from parchment, skins, &c.; as *isinglass*, from the unds of fish—particularly of the sturgeon; as *confec-mers' jelly*, from calves' feet. It is separated from the bumen, with which it is associated, by boiling.

233. When pure, it is transparent, and without colour. swells up in cold, but dissolves easily in hot water: and e solution, on cooling, forms a "jelly," if it contains one rt in 100, of gelatine. It is insoluble in alcohol; but ssolves readily in most dilute acids, and in the fixed alies, from which it is not precipitated by acids. With nnic acid [92], it constitutes leather: and it forms a mpound ($C_{52}H_{40}O_{20}N_8+ClO_4$), with chlorine. It is supsed, by some chemists, to be a product of the decompotion of albumen, or fibrine, by boiling water, rather than distinct body.

234. Ozmazome*, is obtained by boiling down meat oth to dryness: treating the residue with alcohol, and tering. It will be left on the filter. When heated, it nits the odour of roast meat, the smell of which is due to s presence.

235. Vegetable Alkalies.—Besides acids having mpound radicals, there are alkalies having compound ases. They *all contain* nitrogen: and are very import-

* *Ozmē*, odour; and *zōmos*, broth. Gr.

ant, since they confer, on the plants from which they are derived, their most active properties. The chief of them are—nicotine ($C_{10}H_7N$), found in tobacco; coneine ($C_{17}H_{17}N$), in the hemlock; menispermine ($C_{18}H_{12}O_2N$), in the capsules of the coculus indicus, &c.; chinchonine ($C_{20}H_{12}ON$), quinine ($C_{20}H_{12}O_2N$), and aricine ($C_{20}H_{12}O_2N$), in the bark of the various species of chincona; sabadilene ($C_{20}H_{13}O_5N$), jervine ($C_{30}H_{23}O_3N$), and veratrine ($C_{34}H_{21}ON$), in the roots of the veratrum album, &c.; codeïne ($C_{30}H_{21}O_6N$), thebaine ($C_{25}H_{14}O_3N$), morphia ($C_{34}H_{20}O_6N$), and narcotine ($C_{46}H_{27}O_{14}N$), in opium; harmaline ($C_{24}H_{13}ON$), in the seeds of the peganum harmala; delphinine ($C_{27}H_{19}O_4N$), in the seeds of the stavesacre; atropine ($C_{34}H_{23}O_6N$), and belladonnine (composition not yet ascertained), in the atropa belladonna; chelidonine ($C_{40}H_{20}O_6N_2$), and chelerythrine, in the roots of the chelidonium majus; strychnine ($C_{44}H_{22}O_4N_2$), and brucine ($C_{48}H_{26}O_8N_2$), in the nux vomica, &c.:—solanine ($C_{48}H_{79}O_{22}N$), in the berries of the solanum nigrum, in the berries, leaves, &c., of the potato [10]. Also, colchocine, in the seeds of the meadow saffron; emetine, in ipecacuana; aconitine, in the monk's hood; daturine, in the seeds of the thorn apple; hyocyamine, in the henbane; cissampeline, in the roots of the cisampelos pareira; glaucine, in the horned poppy, &c. The constitutions of these latter have not been determined.

Tannic acid, and the soluble tannates, throw down almost all the vegetable alkalies, as white pulverulent compounds, insoluble in water, but soluble in acetic acid.

236. SALICINE*:—$C_{26}H_{18}O_{14}+2Aq$, when crystallized. It is found in the leaves, and bark, of many trees—particularly, in those species of sallow which have a bitter taste. It may be obtained, by boiling the bark three or four times with water; reducing the decoction, by evaporation, to three times the weight of the bark employed, and digesting it for twenty-four hours, with oxide of lead; then evaporating the clear liquid, to the consistence of syrup. After some days, there will be a mass of crystalline fibres, which is to be dried by pressure: and then, purified by re-solution, and digestion with animal charcoal.

237. Salicine crystallizes, when quite pure, in plates, or

* *Salix*, a sallow. Lat.

prisms. It dissolves in eighteen parts cold, and in one part hot water: it is soluble, also, in alcohol. It has a very bitter taste. It fuses at 212°, and crystallizes again on cooling. If boiled with dilute sulphuric acid, it forms grape sugar, and *saliretine* ($C_{14}H_6O_2$). $C_{26}H_{18}O_{14}+2HO=C_{12}H_{11}O_{11}+3HO+C_{14}H_6O_2$. It gives, with basic acetate of lead, a white precipitate ($C_{26}H_{18}O_{14}+3PbO$).

238. CAFFEINE, or THEINE:—$C_8H_5O_2N_2+Aq$. It is found in the coffee berry, tea leaf, &c.: and may be obtained by boiling raw coffee, or green tea, in water; adding subacetate of lead to the decoction, as long as a coloured precipitate is thrown down: and removing the excess of lead by sulphuretted hydrogen. When the filtered liquor is evaporated, and cooled, caffeine will separate in the crystalline form. If coloured, it must be boiled with oxide of lead and ivory black, and re-crystallized. One pound of coffee will yield about fifteen grains caffeine.

239. Caffeine is in the form of brilliant, long needles: it is soluble in fifty parts cold, and in less hot water: but is insoluble in alcohol. It has a bitter taste. Caffeine probably assists in the secretion of bile:—*Taurine* ($C_8H_{14}O_{20}N_2$), the characteristic constituent of bile, contains the elements of caffeine, with nine atoms water, and nine atoms oxygen. It does not seem to have much to do with the flavour of coffee. Caffeine contains much more nitrogen than any other vegetable substance. It is worthy of remark that *theobromine*, a chemical principle found in cocoa beans, is identical with theine and caffeine: and it is curious that so many nations have agreed in using substances similar in the most important constituents, though apparently so different, and obtained from different quarters of the globe: and that this constituent contains more nitrogen than any animal substance, except urea, and uric acid.

240. PIPERINE*:—$C_{34}H_{19}O_6N$. It is found in pepper; and is obtained, by digesting that substance in spirit of wine: evaporating the liquor, to the consistence of an extract: digesting the residue, in a solution of caustic potash —to remove the resin: and dissolving what is left, in alcohol. If the solution is allowed to evaporate spontaneously, piperine will *separate*, in transparent rhombic prisms. It

* *Piper*, pepper. *Lat.*

is without taste, or smell. It fuses at 212°: and becomes red, when treated with nitric acid.

241. THE PUTREFACTIVE FERMENTATION. It should scarcely be considered as a species of fermentation: and is a complete breaking up of the body, more simple compounds being produced with its constituents. Those substances, only, that contain oxygen and hydrogen in the proportions which form water, are disposed to putrefy: and the tendency becomes very great, when bodies already in a state of putrefaction, are present. Thus, a bad apple, or an unsound potato will destroy a large heap of apples, or potatoes. The motion, already existing in the atoms of one substance, overcomes the inertia of those in the other; and causes affinities, of themselves *almost* sufficiently powerful, to come into action. In a similar way, the percussion of a bar of steel will generate, or destroy magnetism [mag. 24] —by enabling the magnetism of the earth, not quite powerful enough of itself, to produce a magnetic effect on the particles of steel.

242. The action of several poisons, is due to decomposition being produced in this way: of all those, for instance, the dangerous properties of which are removed by alcohol, without the latter becoming deleterious: and of those— such as decayed sausages, the virus of the small pox, &c.— from which the poisonous matter cannot be extracted.

243. It is by no means necessary, that a fermenting substance should pass through all the, generally speaking, prior species of fermentation. Acetification, or putrefaction, may take place, without any other fermentation having preceded it. At least, the different kinds may succeed each other so rapidly, that it will be impossible to distinguish them.

244. Putrefaction is prevented by certain substances; and requires certain conditions. If meat is steeped, for a few moments in *creosote** [67] it will not putrefy, even in the sun. Heat is necessary for all kinds of fermentation; and the nature of the latter is, to a great extent, determined by the temperature. Peat bogs are found only in countries, where the climate is not warm enough to cause total decomposition of the vegetable matter. Putrefaction cannot take place under 32°. Salmon, taken in the river

* *Kreas*, flesh; and sōzo, I save. Gr.

Bann, &c., is exported without salt, being packed in ice. Fresh meat is brought, in ice, from America. A large animal was found, some time since, in the polar regions, perfectly preserved by the cold: although it must have been dead a great number of centuries—the very species being long since extinct.

245. Neither can putrefaction take place, if the temperature is higher than 182°. The time during which meat will keep may be prolonged if, after being killed for some time, it is boiled. The high temperature will stop incipient putrefaction, by coagulating the azotized substances.

246. The albumen of animals, or vegetables, is that constituent which first putrefies. If it is coagulated by acids, alcohol, &c.—but, above all, by creosote, putrefaction is prevented. The same effect is produced, by forming insoluble compounds with the albumen, by means of the earthy, and metallic salts. The alkaline salts are not so effective, since they do not precipitate albumen; but they diminish the tendency to putrefaction, by taking up some of the water present, desiccated albumen having no tendency to putrefy.

247. Putrefaction requires the presence of moisture. Salt preserves meat, by combining with the water necessary for its putrefaction. Alcohol, and sugar, also, would have the same effect: and for a similar reason. The affinity of salt for water, makes us thirsty, by taking up that which moistened the coatings of the stomach: and, since only a small quantity is absorbed, an excess of it, passing in the state of solution into the intestinal canal, will dilute what is there and act as a purgative.

248. The presence of air is necessary for putrefaction. Dressed meats, soups, &c., are carried, perfectly fresh, to the most distant regions, in vessels hermetically sealed, and containing no atmospheric air—the latter having been removed from the vessels, and the solids, of the body to be preserved. Eggs may be kept fresh for a considerable time, by rubbing them with an unctuous substance, which, by stopping the pores of the shell, excludes the oxygen of the air. The brine, in which salt meat is preserved, cuts off access of oxygen: since the solution of the salt will not absorb that gas, though pure water will. Hence snow,

which consists of pure water will, from the quantity of oxygen it contains, cause dough to ferment. Hence, also, rain water, and dew, speedily cause putrefaction. For the same reason, dew bleaches rapidly: and it is supposed that the effect of the moon's rays in accelerating putrefaction, is to be attributed to the oxygen in the dew which then falls. But the oxygen exerts a decomposing influence, only when soluble albumen is present. Hence, in preserving meat for the navy, &c., the albumen present is coagulated by heat. Putrefaction is a most powerful deoxidizing agent: it will change yellow into black oxide of iron: and sulphate of iron, into sulphuret. When enormous masses of vegetable matter, have lain under great pressure, and without access of air, peculiar changes occur, coal being formed, and carbon deposited. It is easy, by the aid of the microscope, to detect even the leaves, &c., of which the coal consists; and to determine the species of the plants it contains.

249. Coal is found, in some cases, to have been exposed to intense heat, due to the proximity of igneous rocks; and the expulsion of the volatile elements has produced *anthracite**—a kind of mineral coke, of which Kilkenny coal is a familiar example.

250. Analyses of coal, give different results. This arises from difference in the woods which constitute it; and from the particular stage, to which its gradual formation happens to have reached, &c.

Supposing oak wood to be $C_{36}H_{22}O_{22}$ and that one atom of its hydrogen, and three atoms of its carbonic acid, are removed, the result will be wood coal $C_{33}H_{21}O_{16}$. But, supposing that three atoms carburetted hydrogen, three atoms of water, and nine atoms of carbonic acid are removed, it will be $C_{24}H_{12}O$—isomorphous with Newcastle coal, splint coal, and cannel coal from Lancashire.

251. The mode in which coal-fields have, most likely, been formed, is exemplified in the enormous masses of drifted wood, which are deposited at the mouths of the great American rivers. These will, it is probable, in time, be covered with sand and rocks: in some instances, they will be acted upon by volcanic heat; and all, or most of them,

* *Anthrax*, a coal. Gr.

ay become, hereafter, the supply of future, and far
nt generations. It can scarcely be doubted, that our
al-fields were formed in this way, when these islands
ortions of a mighty continent, whence they have
vered by the gradual inroads of the sea, or by
dden and terrible convulsion.

252. If animal matter is kept, for a long time, with
ontact with air, certain remarkable changes occur. The
ere examined by Fourcroi, when the bodies were remove
om the burial place *Des Innocens*, at Paris. Immens
ultitudes of human beings had been interred, in the
ame pits; and except the hair and bones, the entire mass
as converted into an ammoniacal soap [141]. When
nimal matters decay in presence of a strong base, such as
ime, nitric acid is formed, instead of ammonia—atmos-
heric air being present.

253. Transformations occur, during the putrefaction of
nimal and vegetable substances, which occasionally pro-
luce poisons. Thus putrid meat, mouldy bread, &c.,
ave been known to cause dreadful, and even fatal conse-
uences. Also, wounds that are received during dissec-
ion, and that cause the juices of the dead, to come in con-
act with those of the living body, are of the most danger-
ous character. In certain cases, the poison generated is
gaseous:—thus, what is emitted when the stomach bursts,
after death.

254. Last Products of Decayed Vegetable Mat-
ter.—Wood is sometimes changed into a white friable
substance—seen in the interior of decayed trees. It con-
sists of $C_{33}H_{27}O_{24}$: and is formed, by the combination
of lignine, with oxygen and the constituents of water,
carbonic acid being evolved. $C_{36}H_{34}O_{34}+O_3+3HO=$
$C_{33}H_{27}O_{24}+3CO_2$.

255. When wood has been long acted upon by air and
moisture, *ulmine** ($C_{40}H_{14}O_{12}$), and ulmic acid ($C_{40}H_{12}O_{13}$)
—which is isomeric with saccharohumic acid [165]—are
produced. They are generated, by the woody fibre ab-
sorbing oxygen, carbonic acid, and water, being set free.
Thus, $4C_{12}H_8O_8+O_{14}=C_{40}H_{14}O_{12}+8CO_2+18HO$. The

* *Ulmus, an elm; because originally obtained from that tree in a state of decay.*

ulmic acid is insoluble in water, and alcohol: but dissolves in alkaline solutions. When found in nature, it is combined with ammonia—which it retains so obstinately, that in the attempt to separate them, by means of caustic potash, it is partially decomposed.

256. When vegetable, &c., substances are transformed into the organic parts of vegetable mould, a number of acids, &c., are produced. The most important of these have been divided by Mülder, into the *humic*, and *crenic* groups. The former includes humous acid or *humine* ($C_{40}H_{19}O_{12}$), *ulmine* ($C_{40}H_{14}O_{12}$), *humic* ($C_{40}H_{12}O_{12}$), and *ulmic acid* ($C_{40}H_{12}O_{12}$), &c. Humic acid, though isomeric with the humine of peat, is distinguished from it, by absorbing ammonia with great avidity, and combining with it so strongly that they cannot be separated. The different kinds of humic acid vary, according to the sources whence they are derived:—obtained from black turf, its constituent is $C_{40}H_{15}O_{15}$—the same as that of saccharohumine [165]. When precipitated from its solution in alkalies by sulphuric acid, it is soluble in 2,500 times its weight of water, and forms compounds with the alkalies, lime, and magnesia, of the same solubility. It is not precipitated by acetic acid. After having been dried, or exposed to a freezing temperature, it is insoluble.

Geic acid* ($C_{40}H_{12}O_{14}$), is formed from humic; *appocrenic* acid ($C_{48}H_{24}O_{32}$), from geic; and *crenic† acid* ($C_{24}H_{12}O_{16}$), from appocrenic:—in the upper layer of the soil, appocrenic is formed from crenic acid. According to Mülder, the ammonia of the atmosphere, even without ammoniacal manure, would slowly form ammoniacal salts, with the crenic, and appocrenic acids. Crenic, and appocrenic acid, form salts, also, with the fixed alkalies, lime, magnesia, &c. Appocrenic acid, being penta-basic, is highly valuable: since it is capable of supplying plants with several bases at once. Crenic acid, is tetra-basic. Further decomposition, changes crenic acid into carbonic acid, and water.

* *Gē*, the earth. *Gr.*

† *Krēnē*, a spring, *Gr.*: because first obtained from spring water.

CHAPTER VIII.

Constituents of the most important Vegetable Substances, 257.—Manures, 263.—Animal Manure, 265.—Vegetable Manures, 274.—Mineral Manures, 275.

257. CONSTITUENTS OF THE MOST IMPORTANT VEGETABLE SUBSTANCES.—Agriculture cannot be advantageously pursued, without a knowledge of the elements of those plants which are usually cultivated, of the manures which are most commonly employed, and of the methods by which the constituents of the soil, &c., can be discovered.

Earthy, and metallic substances, are obtained only from the soil. Until a comparatively recent period, it was supposed that, as they were found but in small quantities, they were present by *accident*, and did not constitute any essential portion of the vegetable. It is now, however, universally admitted, that the necessity of replacing them, when they have been removed, is the principal reason for the application of manures. Some crops are evidently better suited than others, to particular soils; but a soil, not naturally adapted to a certain plant, may often, by the judicious application of some substance, be made to afford it in abundance. Chemistry, alone, can supply the knowledge required in these circumstances. By means of it, we ascertain the elements which are necessary to the different vegetables; the constituents of different soils; and the peculiar properties of the various manures. Much depends on climate, and situation, which are beyond our control: but much, also, on the nature of the ground, which may be considered, to a great extent, under the command of industry, and science. An accurate acquaintance with the elements, contained in the various kinds of agricultural produce, and their relative amounts, is indispensable. Almost all of them have been carefully examined, by Boussingault, and others; and the results obtained are most

valuable. The analyses of eminent chemists do not alway agree:—but this is to be expected, since [12] the const tuents of plants are not absolutely invariable.

258. The following is the amount of ashes, in 100 par of the most ordinary trees, &c.:—

TREES.

Species.		Authority.
Alder, young,	0·35	Karsten.
——— old,	0·40	
Ash,	2·30	Mollerat.
Red Beech, young,	0·37	Karsten.
——— old,	0·40	
——— bark,	6·62	Hertwig.
Birch, young,	0·25	Karsten.
——— old,	0·30	
Elm,	2·28	Mollerat.
Lime,	0·40	
Oak, young,	0·15	Karsten.
—— old,	0·11	
—— branches,	0·4	
—— bark,	6·0	Saussure.
—— leaves,	5·5	
Poplar,	1·306	Mollerat.
Pine (P. sylvatica), young,	0·12	Karsten.
——— old,	0·15	
——— needles,	2·60	Saussure.
——— seeds,	4·98	Fresenius and Will
Scotch Fir (P. picea),	0·15	Karsten.
——— seeds,	4·44	Fresenius and Will
Fir (P. abies), young,	0·22	Karsten.
——— old,	0·25	
——— bark,	1·78	Hertwig.
——— needles,	2·90	Saussure.

SHRUBS.

Barberry,	0·71 Mollerat.	Heckle,	1·66 Moll
Blackberry,	0·76 Mollerat.	Heath,	1·41 Moll
Broom,	1·48 Mollerat.	Juniper,	1·84 Moll
Elder,	1·64 Berthier.	Rose (wild),	0·71 Moll
Hazel,	0·50 Saussure.		

HERBS.

Fern,	2·75 Karsten.	Potato leaves,	1·15 Moll
Maize straw,	12·20 Saussure.	Rushes,	4·33 Per
Nettle,	10·67 Pertuis.	Rye straw,	0·30 Kar
Oat straw,	5·10 Boussingault.	Thistles,	4·03 Per
Peas holm,	8·10 Saussure.	Wheat straw,	4·40 Ber
Potato straw,	15·00 Berthier.		

). Constituents of the ashes, according to Berthier—

Soluble.	Alder.	White Beech.	Red Beech.	Birch.	Elder.
onic acid, . .	–	–	3·65	2·72	7·71
huric acid, . .	1·24	–	1·19	0·37	2·06
rochloric acid, .	0·06	–	0·85	0·03	0·13
ic acid, . .	–	–	0·16	0·16	0·06
sh, . . }	–	–	10·45	12·72	21·54
, . . . }					
	18·8	19·22	16·30	16·00	31·50
ot soluble in water.					
onic acid, . .	25·17	26·92	27·53	26·04	22·06
phoric acid, .	6·25	8·11	4·77	3·61	5·83
ic acid, . .	4·06	4·05	4·85	4·62	2·25
e, . . .	40·76	31·31	35·66	43·85	34·57
nesia, . . .	2·03	6·33	5·86	2·52	1·76
e of iron, . .	2·92	1·30	1·25	0·42	0·08
e of manganese, .	–	2·76	3·77	2·94	1·26
	81·20	80·78	83·70	84·00	68·50

difference between their total amounts and 100, is the f any; and, sometimes, the relative weights of con-nts, not examined.

Soluble.	Fir.	Lime.	Mulberry.	Nut tree.	Oak.
onic acid, . .	7·76	2·96	5·82	3·11	2·88
huric acid, . .	0·80	0·81	2·09	0·78	0·97
rochloric acid, .	0·08	6·19	1·01	0·08	0·01
ic acid, . .	0·26	0·17	–	0·08	0·02
sh, . . }	16·80	6·55	13·16	11·27	8·11
, . . . }			2·91		
	25·70	10·8	25·00	15·40	12·00
ot soluble in water.					
onic acid, . .	17·17	35·75	31·75	32·33	34·99
phoric acid, .	3·14	2·51	1·36	4.19	0·71
ic acid, . .	5·97	1·80	2·19	3·67	3·36
e, . . .	29·72	46·53	34·85	37·06	48·41
nesia, . . .	3·28	1·97	3·48	3·84	0·53
e of iron, . .	10·53	0·09	3·38	3·50	–
e of manganese, .	4·48	0·54	0·87	–	–
	74·30	89·20	75·00	84·60	88·00

Soluble.	Pine.	Fern.	Potato straw.	Wh str
Carbonic acid,	2·89	4·35	0·26	tra
Sulphuric acid,	1·67	1·62	0·97	0
Hydrochloric acid,	0·92	3·19	0·50	1
Silicic acid,	0·18	–	–	3
Potash,	4·41	19·84	2·47	5
Soda,	3·53			
	13·60	29·00	4·20	10
Not soluble in water.				
Carbonic acid,	32·77	17·96	–	
Phosphoric acid,	0·91	5·68	–	1
Silicic acid,	4·19	15·48	36·4	73
Lime,	38·51	30·39	–	5
Magnesia,	9·56	0·50	–	
Oxide of iron,	0·09	0·50	–	2
Oxide of manganese,	0·36	0·50	–	7 some
	86·40	71·10	95·80	89

According to Hertwig—

Soluble.	Bean straw.	Pea
Carbonate of potash,	13·32	4
Carbonate of soda,	16·08	8
Chloride of sodium,	0·28	4
Sulphate of potash,	3·24	10
	32·91	27
Not soluble in water.		
Carbonate of lime,	39·50	47
Magnesia,	1·92	4
Phosphate of lime,	6·43	5
Phosphate of magnesia,	6·66	4
Basic ditto of iron,	3·49	0
—— of alumina,		1
Silicic acid,	7·97	7
	65·97	72

According to Fresenius, rye straw consists of—

Soluble.

Silicate of potash,	6·88
Sulphate of potash,	1·75
Chloride of potassium,	0·25
——— of sodium,	0·56
Silicate of lime,	4·19
Magnesia,	0·76
Phosphate of lime,	2·50
——— of magnesia,	1·28
——— of iron,	1·57
——— of manganese,	a trace.
	19·47

Not soluble in water.

Silicate of potash,	9·21
——— of lime,	3·43
——— of magnesia,	1·16
Phosphate of iron,	1·63
——— of manganese,	a trace.
Carbon,	0·94
	80·26

According to Kane—

Flax Plant.

Carbon,	38·72
Hydrogen,	7·33
Oxygen,	48·39
Nitrogen,	0·56
Ashes,	5·00
	100·00

Ashes.

Carbonic acid,	16·95
Sulphuric acid,	2·65
Phosphoric acid,	10·84
Silicic acid,	21·35
Chlorine,	2·41
Potash,	9·78
Soda,	9·82
Lime,	12·33
Magnesia,	7·79
Oxides of iron and alumina,	6·08
	100·00

260. The following may be considered as an average of the constituents, in 100 parts, of the most common vegetable substances:—

	Carbon.	Hydrogen.	Oxygen.	Nitrogen.	Water.	Ashes.
Clover hay,	37·3	3·8	30·0	2·0	21·0	5·9
Jerusalem artichokes	9·1	1·1	9·1	0·3	79·2	1·2
Stems of ditto,	39·8	4·7	39·8	0·3	12·9	2·5
Mangel-wurzel,	5·2	0·8	5·2	0·2	87·8	0·8
Oats,	40·1	5·1	29·1	1·8	20·8	3·1
Oat straw,	35·7	3·9	27·8	0·3	28·7	3·6
Peas,	42·5	5·7	36·6	3·8	8·6	2·8
Pea straw,	40·3	4·5	31·4	2·0	11·8	10·0
Potatoes,	10·6	1·4	10·8	0·3	75·9	1·0
Rye,	39·1	4·8	36·0	1·5	16·6	2·0
Rye straw,	40·6	4·6	33·0	0·2	18·7	2·9
Turnips,	3·2	0·4	3·2	0·1	92·5	0·6
Wheat,	39·4	5·0	37·1	3·0	14·5	2·0
Wheat straw,	35·8	3·9	28·8	0·3	26·0	5·2

261. The following may be considered an average of the constituents, in 100 parts, of the inorganic matter found in *the most common* vegetable substances:—

	Carbonic acid.	Sulphuric acid.	Phosphoric acid.	Silicic acid.	Chlorine	Potash.	Soda.	Chloride of potassium.	Chloride of sodium.	Lime.	Magnes.	Oxide of Iron.
Barley,	–	0·79	31·69	32·73	–	20·77	4·56	–	–	1·48	7·45	0·51
Barley straw,	–	1·63	3·08	70·58	0·97	6·31	0·61	–	–	9·53	3·22	0·83
Beans,	1·94	4·50	31·87	0·88	–	42·13	0·90	0·34	1·90	8·65	6·55	0·36
Bean straw,	22·73	3·21	7·35	3·86	–	21·26	4·56	0·90	9·05	21·29	4·88	0·90
Cabbage,	–	21·48	12·37	0·75	5·77	11·70	20·42	–	–	20·97	5·94	0·60
Carrots,	17·30	6·55	8·55	1·19	–	32·44	13·52	–	6·50	8·83	3·96	1·10
Clover hay (white),	18·03	7·21	11·53	3·68	–	14·33	3·72	–	4·94	26·41	8·15	1·96
Ditto (red),	16·93	4·18	6·35	3·34	–	14·85	1·40	2·96	2·36	35·39	11·22	0·97
Flax seed (Riga),	–	2·47	36·42	10·58	0·17	17·59	6·92	–	–	8·46	14·83	1·25
Flax straw,	10·93	9·38	8·44	14·48	–	7·00	15·68	–	5·87	17·79	4·13	5·13
Mangel-wurzel,	18·32	3·37	3·08	2·57	–	24·79	13·75	–	29·41	1·95	2·11	0·60
Oats,	–	10·45	43·84	2·67	0·26	26·18*	–	–	–	5·95	9·95	0·40
Oat straw,	–	3·26	2·56	48·42	3·25	19·14	9·69	–	–	8·07	3·78	1·83
Peas,	1·82	5·68	34·81	1·24	–	40·19	0·65	1·42	0·68	6·32	6·57	0·59
Pea straw,	14·74	5·66	4·50	5·36	–	17·17	2·48	–	3·57	37·99	6·73	1·76
Potatoes,	–	13·65	12·57	4·23	4·27	55·75	1·86	–	–	2·07	5·28	0·52
Potato straw,	–	6·88	7·62	3·85	12·33	28·02	16·26	–	–	16·90	7·09	1·05
Rye,	–	1·46	47·29	0·17	–	32·76	4·45	–	–	2·92	10·13	0·82
Rye straw,	–	0·83	3·82	64·50	0·46	17·36	0·31	–	–	9·06	2·41	1·36
Rye grass (It.) in seed,	–	1·31	6·32	60·62	–	10·77	0·13	–	5·58	12·29	2·64	0·30
Turnips (Swed.),	–	13·15	6·69	7·05	3·68	39·82	10·86	–	–	12·75	4·68	0·89
Turnip tops,	–	12·52	9·29	0·86	16·05	28·65	5·41	–	–	23·27	3·09	0·86
Wheat,	–	0·24	49·81	1·17	–	23·72	9·05	–	–	2·81	12·03	0·67
Wheat straw,	–	5·82	3·07	65·38	–	12·44	0·16	–	–	6·70	3·81	1·30

* Including soda.

According to eminent chemists, 107 parts of wheat
, as nutriment, to 111 of rye, 117 of oats, 130 of
38 of Indian corn, 177 of rice, 894 of potatoes,
5 of turnips. The cheapest food, therefore, is not
ly the most economical.

MANURES.—Soils may have elements, which are
to the intended crop: or may want some of those
e required by it:—in either case, the remedy is
manure. A soil cannot be good, if it contains
n nineteen parts, in twenty, of any one ingre-
t may have been excellent, originally: but may
come exhausted. Meadows sometimes fail, on
of all the potash having been carried off, with the

ome manures do not require to be decomposed,
y—sea weed, for instance; their constituents
of themselves, with sufficient facility. The less
is decomposed, the better; since its useful ele-
e, to the less extent, dissipated and lost. Hence,
of manure, not decomposed before it is applied,
permanent—though less rapid. If the tempera-
anure is higher than 100°, or if paper, dipped in
oric acid, and held over it, emits fumes of sal-
ic [inorg. chem. 116], we may conclude that its
sition is proceeding too rapidly.

ANIMAL MANURE.—Urine is a most excellent
on account of the great supply of nitrogen which
. That of horses, and cows, contains less nitro-
their solid excrement. Besides nitrogen, urine
large quantities of the phosphates. The following
alysis of human urine, by Berzelius:—

. .	30·10
ic acid, lactate	
onia—and ani-	
tters, not separ-	
m them, .	17·14
. .	1·00
the bladder, .	0·32
of potash, .	3·71
of soda, .	3·16
of soda, .	2·94
Phosphate of ammonia, .	1·65
Chloride of sodium, .	4·45
Sal-ammoniac, . .	1·50
Phosphates of magnesia, and lime—with a trace of fluoride of calcium,	1·00
Siliceous earths, .	0·03
Water, . . .	933·00
	1000·00

The analysis, by Thompson, is as follows:—in 1000 parts.

Phosphate of lime,	0·209
Phosphoric acid,	1·131
Sulphuric acid,	0·481
Chlorine,	5·782
Uric acid,	0·242
Soda,	4·610
Potash,	2·051
Ammonia,	0·130
Urea,	23·640
	38·276

And he supposes them combined, as follows:—

Urate of ammonia,	0·298
Sal-ammoniac,	0·459
Sulphate of potash,	2·112
Chloride of potassium,	3·674
Chloride of sodium,	15·060
Phosphate of soda,	4·267
Phosphate of lime,	0·209
Acetate of soda,	2·770
Urea, with colouring matter,	23·640
	52·489

The rest of the weight being water, and free acid—perhaps lactic.

During putrefaction, urea is changed into carbonate of ammonia. The Chinese have employed urine as a manure, from a very remote antiquity:—and they use no other, in the cultivation of corn.

266. The following is the analysis of human fæces, as given by Berzelius:—

Water,	73·3
Vegetable, and animal, remains,	7·0
Bile,	0·9
Albumen,	0·9
Peculiar extractive matter,	2·7
Salts,	1·2
Slimy matter, consisting of picromel (considered, by some chemists, as one of the constituents of bile), peculiar animal matter, and insoluble residue,	14·0
	100·0

The principal value of excrement, as manure, consists in the salts, which it contains. They were found to consist of—

Carbonate of soda, ...	0·9
Chloride of sodium, ...	0·05
Ammoniacal phosphate of magnesia, . .	0·05
Phosphate of lime, ...	0·1
	1·2

The ammonia in excrements, is the more valuable since, unlike that contained in rain water, it is in a state of combination: and but little of it passes off.

267. Human fæces, contain a variable quantity of nitrogen—but more than those of any other animal. Mixed with clay or, which is still better, with ashes, it emits no disagreeable odour. Lime, also, deprives it of smell:—the sulphuretted hydrogen produces sulphuret of calcium, but some of the ammonia is driven off. In manufacturing fecal matter into manure, at Paris, the offensive odour is entirely destroyed, by mixing it with a solution of sulphate of iron, the sulphuric acid of which condenses the ammonia, and its oxide of iron the sulphuretted and phosphuretted hydrogen.

268. It is not difficult to make a rough estimate of the benefit, which may be expected to arise, from employing this kind of manure. If the solid excrements of a man are supposed to be one quarter of a pound, per day, and his urine one pound and a quarter, as they contain three per cent. nitrogen, they will be equivalent to 16·425 lbs. of that element, in the year. This being enough to supply nitrogen, for 800 lbs. of wheat, rye, or oats, or for 900 lbs. of barley is, along with what is derived from the atmosphere, sufficient to make an acre of ground yield the richest crop. And, to put the matter in the simplest point of view, it may be stated, that a pint of urine is equivalent to a pound of wheat. Half the nitrogen of urine will escape into the atmosphere, during its putrefaction, unless a weak mineral acid is used to neutralize it. When human excrement is employed for manure, the seeds of weeds—which pass *through* animals unchanged—are not sown. *Hence, in China,* weeds are never seen in corn fields, since

they are manured [265] with urine, only. The urine of different animals, and indeed of the same animal according to its age, food, &c., varies, as to the quantity, and nature, of the solid ingredients it contains. In a year,

	lbs.		lbs.	
A man produces	1,000	of urine, containing	67	solid matter.
A horse ,,	1,000	,,	89	,,
A cow ,,	13,000	,,	1,023	,,

1,000 parts of the urine of a man, a cow, a horse, a pig, and a sheep, contain—

	Water.	Organic Matter.	Inorganic Matter.
Man, . .	933·00	48·56	18·44
Cow, . .	921·32	41·98	36·70
Horse, . .	910·76	48·31	40·93
Pig, . .	978·80	5·24	15·96
Sheep, . .	960·00	28·00	12·00

The urine of man, and of the pig, is rich in phosphates; and, therefore, well adapted for seed crops.

269. The comparative amounts of the elements, in 100 parts horse, and cow dung, are as follow—

	Horse.	Cow.
Water, . .	78·36	79·724
Organic matter, .	19·10	16·046
Inorganic matter, .	2·54	4·230
	100·00	100·00

The inorganic matter consists of—

	Horse.	Cow.
Phosphate of lime, . .	5·00	10·9
Phosphate of magnesia, . .	36·25	10·0
Carbonate of lime, . .	18·75	00·0
Phosphate of iron, . .	00·00	8·5
Carbonate of potash, . .	00·00	1·5
Sulphate of lime, . .	00·00	3·1
Silex, ...	40·00	63·7
Loss, ...	2·30	00·0
	100·00	100·00

270. The excrement of birds, contain a large quantity of uric acid [55];—it forms the white, and nearly crystalline part; and is due to their urine, which is present and assumes the solid form. Hence, guano—the excr

ment of sea-fowl—which contains about one-fourth of its weight of uric acid, has such fertilizing properties. It is found, from analysis, to consist of—

Urate of ammonia,	9·0
Oxalate of ammonia,	10·6
Oxalate of lime,	7·0
Phosphate of ammonia,	6·0
Phosphate of magnesia and ammonia,	2·6
Sulphate of potash,	5·5
Sulphate of soda,	3·8
Sal-ammoniac,	4·2
Phosphate of lime,	14·3
Clay and sand,	4·7
Organic substances—containing 12 per cent., insoluble in water: soluble salts of iron, in small quantities; water,	33·3
	100·0

The excrements of a boa constrictor, contain nine-tenths of their weight, urate of ammonia.

271. 100 parts bones, on account of their gelatine, contain as much nitrogen as 250 lbs. of human urine. According to analysis, they are found to consist of—

Organic matter, driven off, by heat,	33·25
Phosphate of lime,	55·50
Phosphate of magnesia,	3·00
Carbonate of lime,	3·75
Salts of soda,	3·50
Fluoride of calcium,	1·00
	100·00

272. The following, will give an idea of the relative proportions of the ingredients contained in bone, shell, and crust [inorg. chem. 319].

Bone—Human, and ox bones, by Berzelius:

	Human.	Ox.
Cartilage, soluble in water,	32·17	33·30
Vessels,	1·13	
Carbonate of lime,	11·30	3·85
Phosphates of lime,	54·20	59·40
Soda, and a little chloride of sodium,	1·20	3·45
	100·00	100·00

Shell—Oyster shells, according to Bucholz and Brandes:

Albuminous matter, . . .	0·5
Lime, ...	54·1
Carbonic acid, . . .	44·5
Phosphate of lime, . . .	1·2
Alumina, ...	0·2
	100·5

Crust—Lobsters' claws, lobsters' shell, and hens' egg shell, by Pagurus:

	100 parts Lobsters' claws.	Lobsters' shell.	Hens' egg shell.
Animal matter, .	17·18	28·6	4·7
Soda salts, . .	–	1·6	–
Carbonate of lime, .	68·36	62·8	89·6
Phosphate of lime, .	14·06	6·0	5·7
Phosphate of magnesia,	–	1·0	–
	99·60	100·0	100·0

273. We have already mentioned [232] that the relative amounts of the constituents of bones, are not always the same. They are valuable sources of phosphoric acid, which is a most important element, in plants. Most seeds contain phosphates of lime, and magnesia: and, the larger the amount of these salts, the more nutritious the seeds are. Lentils, beans, and peas, on account of the small quantity of these substances found among their constituents, do not strengthen animals that feed on them, so much as others which contain less nitrogen. Bones appear to be improved, as manure, if deprived of their fatty matter, by boiling:—it probably facilitates the decomposition of their gelatine. If rain is excluded, they may be preserved, when whole, for an indefinite period: but, if they are finely divided, and moistened, their temperature rises, and they putrefy. Cattle are slaughtered in South America, to supply us with their bones, for the improvement of our fields. Bone manure is very conveniently prepared for use, by pouring over it, half its weight of sulphuric acid, diluted with four times its weight of water; and, after it is digested for some time, adding 100 parts water. The *resulting* mixture may be sprinkled before the plough.

Various other animal substances are employed as ma-

nure—such as fish, the flesh of animals, blood, the parings of skins, and horns, hair, and woollen rags, &c.

274. VEGETABLE MANURES.—They consist of decaying, or useless vegetable matter, bog-stuff, sea-weed, &c.: and, sometimes, of the ashes derived from these substances. The kind of manure, which the various plants may be expected to produce, can easily be learned, from what we have already said [258], when speaking of their constituents. It must, however, be borne in mind, that [12] the same plant may, in different circumstances, contain variable quantities of its inorganic elements.

1,000 parts, peat, may be considered to consist of:

Carbon,	580·90
Hydrogen,	59·30
Oxygen and nitrogen,	313·70
Sulphates of potash, soda, and magnesia,	6·73
Sulphate of lime,	10·75
Phosphate of lime,	0·92
Carbonate of lime,	8·76
Siliceous earth,	11·15
Alumina,	3·07
Oxide of iron,	4·72
	1000·00

The sea-weed, found on our coasts, contains, in 100 parts, about 77·97 water, 16·57 organic matter, and 5·46 ashes.

275. MINERAL MANURES.—One of the most important of these, is *lime*. It is injurious, in the caustic state; but it soon loses its causticity, by decomposing animal or vegetable matter, and uniting with the carbonic acid, formed from their elements. In this way, it breaks up their fibres, and facilitates their decomposition. Magnesia remains caustic much longer than lime: and, hence, unless the land is rich, or contains a considerable quantity of organic matter—which affords a greater facility of obtaining carbonic acid—it is very mischievous.

276. Quick lime is useful, when a salt of iron is present. If, for example, it is added to a soil that is injured by sulphate of iron, the results are sulphate of lime, and oxide of iron—which combining with the oxygen of the atmosphere, will form peroxide, a harmless substance. *Protoxide is pernicious, on* account of its affinity for oxygen.

and, hence, red earth—which contains it in large quantities—should be brought to the surface, that it may be peroxidated as soon as possible. A similar affinity for oxygen, renders mould, which is capable of imparting a colour to water, hurtful to plants.

Carbonate of lime may be advantageous in bogs, by removing the acids which prevent decomposition.

277. *Gypsum* assists the growth of grasses, by fixing ammonia—carbonate of lime, and soluble sulphate of ammonia being formed. Since it is decomposed but slowly, it will last for a long time. Water is necessary for its decomposition, and for conveyance of the ammoniacal salt to the plant. Dry fields, therefore, are but little improved by gypsum. It absorbs the ammonia evolved by night-soil, and in stables: and destroys the disagreeable smell. 100 lbs. gypsum, fixes as much ammonia, as would be derived from 6,880 lbs. of the urine of horses. If the ammonia, produced in stables, is not fixed, it will form nitric acid: which will gradually act upon the walls. This injurious action is, in Germany, termed "salpeterfrass."

278. Sulphuric acid, added to a calcareous soil, produces gypsum. 100 parts, by weight, oil of vitriol, will afford nearly 142 parts sulphate of lime. The acid should be diluted with about eight or ten times its weight of water.

279. If a soil contains too much calcareous matter, it will be improved by sand.

280. There are many other kinds of manure: but, generally speaking, the reason, and amount, of their utility, may easily be inferred, from what we have already said of those chemical compounds, which are of any importance.

CHAPTER IX.

CHEMICAL ANALYSIS.

Nature of the Process, 1.—Qualitative Analysis of Water, 2.—Quantitative Analysis, 17.—Qualitative Analysis of Organic Substances, 49.—Quantitative Analysis, 55.—Analysis of a Soil, 68.—Organic Constituents of the Soil, 72.—Constituents of the Soil, which are soluble in water, 79.—Constituents, which are soluble in dilute hydrochloric acid, 86.—Constituents, which are insoluble in water, and dilute acids, 90.—Constituents, which are insoluble in water, and acids, 91.

1. NATURE OF THE PROCESS.—Chemical analysis* is of two kinds—the *qualitative* and the *quantitative*. By the former, the *nature* of the constituents, contained in the body to be examined, is ascertained; and by the latter, their *relative amounts*. In making an analysis, the operator should avail himself of every means, that suggest themselves, for securing delicacy, and exactness. Habits of neatness, and care, and a certain amount of skill in manipulation, are required in all experimental researches —but, most particularly in those which have analysis for their object. The strictest conscientiousness, in detailing particulars, is indispensably necessary:—without it, analysis is worse than useless. No person need be ashamed, that his results are a little more, or a little less, than, theoretically, they should be. Indeed, their *perfect* correspondence with what might be expected, is no proof of their real accuracy: for, looking to our, at best, imperfect resources, they cannot be mathematically exact. Whatever incorrectness, therefore, is found in them, should be candidly stated, if inconsiderable; but, if considerable, the analysis should be repeated. An inaccuracy should never be divided among the several items; since, besides

* *Ana,* severally; and *luo,* I set free. Gr.

other evils, this renders a verification impossible. An analysis, in which there is a defect, is more likely to be correct, than one in which there is an excess. Several experiments should be made: and the more nearly they agree, the more they are to be depended on. The average and, at least, the highest and lowest of the results, carefully obtained, should be mentioned. The different parts of the analysis should be made, as far as practicable, to check each other. Sometimes it will be found possible to ascertain, with more or less of probability, the element in which a loss has occurred:—as, for example, when, the deficiency being added to some particular element, the results will all be in atomic proportions. It is scarcely possible to state, in general terms, what extent of error may be considered allowable; since it depends on circumstances. Thus, in determining the amount of chlorine, a loss greater than one part in 1,000 must not be tolerated; while, in estimating strontia, by means of sulphuric acid, a loss ten times as great, should not be considered unreasonable.

The difficulty of determining the quality of a soil, by analysis, may be understood, by considering how much a square acre one foot deep weighs, and how amazingly small a per centage will be added to it of any ingredient, by means of manure. Thus suppose the quantity of manure allowed per acre contains 100 lbs. of ammonia, a very liberal allowance, the quantity per cent. of it in the mass would not be discoverable by our best method of analysis: yet it would double the product in wheat; and make the difference between an exhausted, and a highly productive soil.

The subject is so extensive, that we can direct attention to only a few general principles. These, however, along with what we have said, in treating of the different elements, and their compounds, will enable the student to pursue many interesting, and important researches, particularly with reference to agriculture.

2. Qualitative Analysis of Water.—*Carbonic acid.* If, on adding lime water, to a portion which has been recently collected, and kept in a well-stopped bottle, a precipitate is thrown down, and is redissolved by adding more of the water, it contains free carbonic acid [inorg. *chem.* 270].

3. *Sulphuretted hydrogen.*—It will be detected by the smell: and will be rendered still more evident, on adding acetate of lead. If either sulphuretted hydrogen, or an alkaline sulphuret, is present, there will be a black precipitate or, at least, the water will be darkened [inorg. chem. 549]. Long continued contact with the cork, may change sulphates into sulphurets: from which sulphuretted hydrogen will then be evolved, by the free carbonic acid present.

4. *Sulphuric acid.*—If, after acidifying the water, with a little hydrochloric acid, and gently warming it, a white precipitate is thrown down, by chloride of barium, sulphuric acid is present [inorg. chem. 309].

5. *Chlorine.*—If, after acidifying with a little nitric acid, and warming, nitrate of silver throws down a curdy precipitate, or causes turbidity, chlorine is present [inorg. chem. 333].

6. *Nitric acid.*—It will be detected, by evaporating a large quantity of the water to dryness, dissolving the residue in water, adding sulphuric acid and, then, protosulphate of iron [inorg. chem. 243].

7. *Iodine.*—When four or five gallons are evaporated to a very small quantity, iodine may be detected, by means of starch [inorg. chem. 363].

8. *Bromine.*—The presence of this substance may be ascertained, with chlorine water, and ether [inorg. chem. 367].

9. *Fluorine.*—Several gallons are evaporated, to dryness: and, the residue being dissolved in hydrochloric acid, ammonia is added to the solution. The precipitate obtained, is heated with sulphuric acid, in a platinum crucible covered with a glass plate. Fluorine will then, if present, be indicated by the latter [inorg. chem. 372].

10. *Lime* is detected with oxalate of ammonia [inorg. chem. 468].

11. *Carbonate of lime* dissolved in carbonic acid, will render the water cloudy when it is boiled, carbonic acid being evolved [inorg. chem. 270].

12. *Magnesia.*—After separating the oxalate of lime [10], by filtration, and concentrating the filtered liquor by evaporation, it will be seen if magnesia is present, by

adding phosphate of soda and ammonia [inorg. chem. 558].

13. *Iron.*—If, on adding to some of the water, a few drops of lime water, and some tincture of galls, a dark precipitate is produced, iron is present [inorg. chem. 538]. It will be necessary to test for iron, before boiling: as it is, most frequently, contained in water as a carbonate. If it is found after boiling, it must have been in combination with some other acid.

14. *Potash.*—The iron, contained in some of the water, being brought to the state of peroxide [inorg. chem. 538], carbonate of ammonia is added: and, the resulting precipitate being removed, the filtered liquor is evaporated to dryness, and ignited. The residue is dissolved in water, and a solution of barytes is added, as long as it causes any precipitate. The liquor, being then boiled, is filtered and, sulphuric acid being added, to throw down the excess of barytes, refiltered. After this, it is evaporated to dryness, and the residue is dissolved in alcohol. If, on igniting some of the alcoholic solution, the flame has a violet tinge, potash, but not soda, is present: and if, on mixing it with chloride of platinum, a yellow precipitate is at once formed, the presence of potash becomes still more evident [inorg. chem. 623].

15. *Soda.*—If, when the alcoholic solution is ignited, the flame is yellow, soda is present; and it may be precipitated, by antimoniate of potash [inorg. chem. 652]. If it has been previously ascertained, that there is no magnesia, it is not necessary to add the barytic water, in looking for the potash, and soda.

16. *Ammonia.*—If, a few drops of hydrochloric acid being previously added, a large quantity of water is evaporated to dryness by a gentle heat, caustic potash, or hydrate of lime, will show whether or not ammonia is present [inorg. chem. 254].

If it contains other substances, their quantity must be small: and they may be discovered, in the subsequent quantitative analysis.

17. Quantitative Analysis of Water.—*Specific gravity.* It is proper to ascertain this; which may be found, by means of the specific gravity bottle [hyd. 55], the temperature being 60°.

18. *Carbonic acid.*—A known quantity of the water is placed, at the spring, in well-stopped bottles, along with some chloride of calcium, and ammonia—quite free from carbonic acid. This will cause carbonate of lime to be thrown down. $CaCl + NH_4O + CO_2 = (CO_2 + CaO) + NH_4Cl$. The precipitates are collected, and placed in a small thin bottomed flask A, fig. 30, which contains water and hydrochloric acid—in a small test tube: and has been fitted with a cork, in which is inserted a bent tube D, that connects it with the apparatus B—nearly filled with fused chloride of calcium, in fragments. When the weight of the whole apparatus has been ascertained, the flask A is so inclined, that small quantities at a time, of hydrochloric acid, may fall upon the carbonate; and, as soon as effervescence ceases, the flask is placed in boiling water, to expel the carbonic acid—which passes off through an aperture at E. The aqueous vapour, which leaves the flask, is intercepted by the chloride of calcium in B; and the atmospheric air, which enters as the apparatus cools, causes the interior to be as it was at the commencement. The difference of weight, therefore, before and after the process, will indicate how much carbonic acid has been evolved by the carbonate.

Fig. 30.

This apparatus is well suited to the analysis of limestone, marl, &c.

19. To ascertain how much carbonic acid is in combination with the fixed alkalies. About 5,000 grains of the water are boiled for some time, and filtered:—hot water is used in washing; and what passes through the filter, is added to the rest of the clear liquor. The latter is then divided into two portions: nitric acid is added to one, and its chlorine being precipitated with nitrate of silver, the resulting chloride is dried, &c., and weighed: the other hav-

ing been acidulated with hydrochloric acid, the chlo
then contains is precipitated, dried, &c., and we
The larger amount of chlorine, in the latter case, is
the carbonic acid which, having been combined with
alkalies, was driven off by the hydrochloric acid. 100
excess of chloride, are equivalent to 15·34 grains ca
acid.

20. *Sulphuretted hydrogen.*—Some bottles, in w
small quantity of arsenious acid dissolved in hydroc
acid has been placed, are filled, at the spring, with a l
quantity of the water; and the sulphuret of arsenic (
that will be thrown down, is washed, dried at 212
weighed. It contains 39·05 per cent. sulphur; a
quantity of sulphuretted hydrogen may easily be de
from this.

21. *Solid ingredients.*—To ascertain what amou
these is contained in the water, 1,000 grains of
evaporated to dryness, in a platinum crucible, place
water bath: and the residue is dried, at various te
atures, and weighed—that degree, above which no fu
diminution occurs, being noted. This will give a
proximation to the quantity of solid matter. It will,
ever, be only an approximation; since ammoniacal
may have been set free; and earthy chlorides may
been decomposed at a temperature higher than 212
account of water having been removed.

22. *Sulphuric acid.*—About 8,000 grains of the
are acidified with hydrochloric acid, and precipitated
chloride of barium. The resulting sulphate of ba
being allowed to rest for twenty-four hours, is filtered,
and heated, to redness, in contact with the air—wi
which it would be changed into sulphuret of barium
contains 34·37 per cent. sulphuric acid.

23. *Nitric acid.*—About a gallon of the water is e
rated, down to a few ounces, and filtered: and the
liquor is macerated, with enough of sulphate of silv
change the chlorides, iodides, and bromides, into sulp
The resulting precipitate is removed, and the clear li
having been rendered alkaline with carbonate of so
concentrated in a water bath; then mixed, in a tubu
retort, with more than ·ch pure sulphuric acid.

iously boiled—to change all the ingredients present, into isulphates; and, afterwards, heated in a sand bath. The apours which pass over are to be conducted into a glass eceiver, containing a solution of hydrate of barytes—the istillation being stopped, as soon as vapours of sulphuric cid begin to rise. The fluid in the receiver is evaporated n a water bath, almost to dryness; and the residue is exosed to the air, for about twelve hours—to change the exess of hydrate into carbonate of barytes, which is removed, y filtration. And, lest any carbonate should be dissolved, ne evaporation almost to dryness, and the filtration, should e repeated. When all the carbonate has been taken away, ilute sulphuric acid is added, and the resulting sulphate f barytes is washed—at first, with boiling distilled water —dried, and ignited. It contains 65·63 per cent. barytes, hich corresponds with 46·4 nitric acid.

24. *Phosphoric acid.*—About 80 lbs. of the water are vaporated to something more than two, and filtered—the ashings being added to the mother liquor. Both the mother liquor," and the "precipitate," will be required or several purposes: they must, therefore, be accurately eighed, that the quantity of each, corresponding to a iven amount of the water, may be easily known. One-alf of the precipitate is then dissolved in hydrochloric acid, nd precipitated with acetate of lead; and the resulting hosphate of lead—which is not of an invariable composion—being collected on a filter, washed, dried, ignited, nd weighed, is dissolved in as little nitric acid as possible, nd precipitated with sulphuric acid—alcohol being added, o prevent any of the sulphate of lead from being dissolved. he sulphate is to be collected on a filter, washed with ilute alcohol, ignited, and weighed. It contains 73·64 per ent. oxide of lead; which, being deducted from the weight f the phosphate of lead, gives that of the phosphoric acid.

25. *Chlorine, iodine,* and *bromine.*—About 15,000 rains of the "mother liquor" [24], are evaporated to dryess, along with some carbonate of soda: and the residue digested, several times, with alcohol. The alcoholic exract is evaporated to dryness, and the residue, having been ently ignited *in a platinum crucible*—to destroy any or*anic matter present*—is dissolved in water, and filtered.

The clear liquor is carefully neutralized with hydrochloric acid, and precipitated with protochloride of palladium. The protoiodide of palladium, which is thrown down, after being allowed to rest for twelve hours, is separated by filtration, washed with warm water, and dried at a temperature below 212° or, which is better, with sulphuric acid, *in vacuo*. It contains 70·53 per cent. iodine.

26. The fluid, from which the protoiodide of palladium has been removed, is saturated with sulphuretted hydrogen —to throw down the excess of palladium; then filtered, boiled with nitric acid, again filtered—if necessary, and precipitated with nitrate of silver. The resulting precipitate—which contains all the chlorine and bromine, as chloride and bromide of silver—having been washed, dried, fused, and weighed, is introduced into a bulbed tube of hard glass, of a known weight: and, the silver salts being kept in a state of fusion, and agitated occasionally, a current of chlorine—dried by transmission through fused chloride of calcium—is passed into them. When the process has been continued for about half an hour, the tube is allowed to cool, and being freed from chlorine, by a current of atmospheric air, is weighed. After this, chlorine is again passed into the salts, in a state of fusion, and the excess is expelled by atmospheric air, as before. If the weight has not been altered, by the second application of chlorine, enough of that substance has been employed, and the difference between the weights, before and after it was transmitted, arises from the bromine having been displaced by chlorine. For every grain, diminution of weight, there were 4·22 grains of bromide, in the mixed silver salt; and the bromide, contained 42·56 per cent. bromine. The weight of the mixed chloride and bromide, minus the weight of the bromide, is the weight of the chloride; and the chloride contains 24·74 per cent. chlorine.

27. *Fluorine.*—If this is present, it must be in very small quantity. We shall, hereafter, point out the mode of determining its weight, when the latter is too large to be neglected.

28. *Silex, iron, lime, magnesia, and alumina.*—About 12,000 grains of the water are placed, along with some nitric acid, in a large glass flask, and the carbonic acid is

expelled by heat. It is then evaporated to dryness, in a porcelain basin, and a water bath: and the residue, having been heated in a sand bath until the moisture has been completely expelled, is digested with hydrochloric acid, and a gentle heat is applied: water is added occasionally, and the mixture is kept stirred. The silicic acid, which has been rendered insoluble by drying [inorg. chem. 377], is washed with hot water, dried, ignited, and weighed—while hot, or after it has been cooled, with sulphuric acid under an exhausted receiver.

29. Ammonia being added to the liquor, from which the silex has been taken, hydrated peroxide of iron is thrown down: and, the mixture being heated nearly to ebullition, the peroxide is removed by filtration, washed with hot water, dried, and ignited. If it is not well washed, some of the iron will be volatilized, as perchloride. Should it be ignited with the filter [inorg. chem. 54], some of it may be reduced—particularly when there is not free access of air: but moistening with nitric acid, and reheating, will re-peroxidate it.

30. If the precipitated peroxide of iron is not of a fine brownish red colour, it arises from the presence of alumina, or phosphoric acid. In such a case, after being well washed, it is dissolved in hydrochloric acid; and caustic potash, in slight excess, is added to the solution. The resulting precipitate is removed from the alkaline liquor—which contains any alumina present—by filtration; and, being washed, is redissolved in hydrochloric acid. Ammonia in excess is added to the solution, to neutralize the free acid, then hydrosulphuret of ammonia, and a gentle heat is applied. The vessel is covered with a glass plate, and left at rest, in a moderately warm place, until the liquor acquires a yellow tint, if it has not that colour already. The precipitated sulphuret of iron is removed, by filtration, and is washed continuously, with water containing a little hydrosulphuret of ammonia. If the funnel is left uncovered during the filtration and washing, the iron will be oxidated, and a soluble protosulphate will be formed: should this take place, reprecipitation will be caused, by the hydrosulphuret of *ammonia*, in the receiver underneath. When the *sulphuret of iron is* well washed, it is transferred, along

with the filter, to a glass jar, and redissolved by hydrochloric acid, the sulphuretted hydrogen being driven off by heat. The solution is filtered into a flask, and well washed through the filter: after which the iron is peroxidated with nitric acid, precipitated with ammonia, and treated as we have already described [29].

31. *Alumina.*—The alkaline solution containing it [30], is moderately diluted; and a rather large quantity of sal-ammoniac being added, and then ammonia in excess, heat is applied; after which, the precipitate is removed by filtration, washed, dried, ignited, and weighed. A gentle heat must be employed at first, and the crucible must be kept covered; otherwise, a portion of the gelatinous hydrate will be thrown out. All the water is driven off, by the high temperature, and the residue is pure alumina.

32. *Lime.*—When the iron, and alumina, have been precipitated by ammonia [30], and removed, ammonia is added to the washings, until its smell is perceptible: and then, oxalate of ammonia, to throw down the lime. Previous to filtration, the vessel is covered, and left in a warm place, until the precipitate subsides: without this precaution, it would pass through the filter. Should any of the oxalate adhere firmly to the glass, it must be dissolved off by hydrochloric acid; and, being precipitated with ammonia, must be thrown on the filter, along with the rest. The oxalate having been well washed, and dried, is ignited: and the ignition is continued, for about a quarter of an hour after the bottom of the crucible has begun to glow: it is then cooled, and weighed. If too great heat has been applied, the ignited precipitate, on being moistened, will change turmeric paper to brown—on account of the presence of caustic lime. When this occurs, the turmeric paper must be rinsed into the crucible—that nothing may be lost; and, a bit of carbonate of ammonia being added, the precipitate is evaporated to dryness, in a water bath, and again weighed. The residual carbonate, contains 56 per cent. lime.

33. *Magnesia.*—After the lime has been removed, phosphate of soda in excess, is added to the clear liquor—which is to be stirred with a glass rod, but without touching the sides [inorg. chem. 558]. At the end of twelve hours, the

precipitate is thrown on a filter, and washed with a mixture containing one part solution of sal-ammoniac, and seven parts water, until a drop of the washings leaves no residue, when evaporated on platinum. As soon as the precipitate is dry, it is ignited in a platinum crucible, a gentle heat being, at first, applied. The resulting pyrophosphate (PO_5+2MgO) contains 36·64 per cent. magnesia.

34. The iron, lime, and magnesia, which were thrown down, by boiling—and, therefore, were dissolved by free carbonic acid—may be ascertained by boiling 10,000 grains of the water in a glass flask, for about an hour: distilled water being occasionally added, to prevent the sulphate of lime from being precipitated. The precipitate is then removed by filtration, dissolved in dilute hydrochloric acid, and heated with some nitric acid. The iron, &c., which it contains, may be thrown down, as usual [29, 32, and 33].

35. *Strontia.*—The remainder of the "precipitate" [24], is dissolved in hydrochloric acid: then ammonia in excess, and hydrosulphuret of ammonia, are added to the solution. The precipitate—containing sulphurets of iron, manganese, and alumina—being removed by filtration, a solution of gypsum is added to the clear liquor, to throw down sulphate of strontia. As this is slightly soluble in water, but is nearly insoluble in alcohol, and spirits of wine, alcohol is poured into the liquor, and, after the precipitate is placed in the filter, it is washed with spirits of wine. When dried, and ignited, it contains 56·36 per cent. strontia.

36. *Manganese.*—The precipitate, containing the iron, manganese, and alumina [35], being well washed, is dissolved in hydrochloric acid, and heated with nitric acid—to peroxidate the iron [inorg. chem. 330]. Caustic potash, which throws down only the iron and manganese, is added in excess: and the mixed precipitate is filtered, washed, and dissolved in hydrochloric acid. An extremely dilute water of ammonia is dropped into the solution, very gradually, until the fluid acquires a brown red colour, on account of a slight precipitation of iron. If the latter is not redissolved by heat, enough ammonia has been added: but if the *fluid is* rendered colourless by it, too much ammonia *has been used:* and, the excess being neutralized by

hydrochloric acid, ammonia must be again poured in, wit more caution than before. When the proper quantity ha been employed, a perfectly neutral solution of succinate o ammonia is added, as long as any precipitate is throw down, and a gentle heat is applied. As soon as the flui cools, the precipitate is removed, and the clear liquor bein placed in a capacious flask, and heated to 212°, carbonat of soda in excess is added, until the escaping vapour cease to render turmeric paper brown. The resulting precipitat is filtered, dried, and changed from carbonate of manganes to manganoso-manganic oxide (Mn_3O_4)—by heating to red ness, with access of air. It contains 72·1 per cent. metallic manganese.

37. *Fixed alkalies.*—About 10,000 grains of the wate being evaporated to 6,000, they are mixed with excess o barytic water, and filtered. Carbonate of ammonia i added to the washings—to remove the lime, and excess o barytes—and the filtration is repeated. The washing are evaporated to dryness, ignited, and redissolved i hydrochloric acid—to bring the alkalies to the state o chlorides; then evaporated, again, to dryness, ignited, an weighed. The residue is dissolved in water, and precipi tated with an aqueous solution of bichloride of platinum in excess; and the mixture, having been evaporated t dryness in a water bath, is heated with spirits of wine, con taining from 76 to 80 per cent. alcohol. After some hours the potassio-chloride of platinum is removed from the solu tion of sodio-chloride, by filtration. If the clear liquor i not of a deep yellow colour, enough bichloride of platinum has not been used. The potassio-chloride is washed on t filter, with spirits of wine: then dried, at 212°, and weighed It contains 16·01 per cent. potassium: and 30·52 per cent chloride of potassium. The chloride of potassium, deducte from the mixed chlorides of potassium and sodium, wil give the chloride of sodium.

38. If the alkalies, in the water, are combined wit phosphoric acid, before converting them into chlorides, th ignited mass is redissolved in water, and precipitated wit neutral nitrate of silver—to take away the phosphoric acid The excess of nitrate is removed, with hydrochloric acid.

39. If they are in combination with boracic acid, &

ignited mass is digested, in a platinum crucible, with three or four parts pulverized fluor spar, and concentrated sulphuric acid—heat being applied as long as fumes are given off. This changes the boracic acid into gaseous fluoride of boron, and the alkalies into sulphates, which may be changed into chlorides.

40. *Ammonia.*—A large quantity of the water is to be slightly acidified with hydrochloric acid, and concentrated by evaporation. The concentrated liquor is mixed in a tubulated retort, with a large quantity of caustic soda, and boiled for a long time—the vapours being condensed in a receiver, containing dilute hydrochloric acid, and surrounded with ice, or cold water. When the fluid has boiled down to two or three ounces, bichloride of platinum is added to what has distilled over, and the mixture is evaporated to dryness, in a porcelain vessel. The residue, after being lixiviated in a mixture, consisting of two volumes of alcohol, and one of ether—in which the ammoniochloride is perfectly insoluble—is dried at 212°, and then weighed. It contains 8·07 per cent. ammonium, which corresponds with 7·622 ammonia.

41. *Lithia*, if its presence is suspected. Ten or twelve gallons of the water are evaporated down to about a pint, and then—the precipitate which has formed having been removed—to dryness, along with carbonate of soda. The residue, after being heated with boiling water, is filtered, and the clear liquor is mixed with phosphate of soda, and evaporated to dryness. On adding water—as there is an excess of phosphate of soda—the resulting phosphate of soda and lithia, will be quite insoluble, and may be removed. This double phosphate consists of an atom of phosphoric acid, combined with three atoms of fixed base: it dissolves in 1,400 parts water at 59°, and 951 parts at 212°. But soda, and lithia, being isomorphous, more, or less, of the base may be lithia :—its constitution, therefore, is variable. Hence, after being dissolved, its phosphoric acid is removed with nitrate of silver; and the excess of nitrate, with hydrochloric acid. The soda and lithia are then changed to chlorides: the liquor containing them is *evaporated to dryness*: and the chloride of lithium (LCl) *is separated from* the chloride of sodium, by a mixture

containing equal parts absolute alcohol and ether—wh dissolves the chloride of lithium, and but a trace of chloride of sodium. The chloride contains 15·59 per ce lithium: which is equivalent to 34·63 lithia.

42. *Organic matter.*—The total amount of this, c tained in the water, may be ascertained, by boiling do a large and known quantity; evaporating it to dryn with carbonate of ammonia; drying the residue, at 28 and weighing; then igniting, till the dark colour, at f produced, has disappeared, and again weighing. The ference between the weights will indicate the amount organic matter.

When we describe the analysis of soils, we shall po out the methods of estimating the various organic s stances, which are likely to be found in water, or soils.

43. *Results of analysis.*—In arranging these, the d at which the water was collected, is to be stated: also, precise part of the river, &c.: the temperature of the mosphere, and of the water; the specific gravity of latter; the substances detected, during the "qualitativ and those examined during the quantitative analysis— amount of water employed in looking for each, and the centage obtained, being specified. Thus, let two exp ments have been made, to determine the amount of chlori 6,000 grains of water being employed, in one, and 8,00 another. Let the chloride of silver, obtained in the for case be 0·383 grains, and in the latter, 0·523 grains:— noting may be as follows—

	Quantity of water.	Chloride of silver.	Per centage of chlorine.
I.	6,000	0·383	0·001579
II.	8,000	0·523	0·001617
			Mean, 0·001598

44. The salts that are thrown down by boiling may considered as carbonates, kept in solution by carbonic a

45. The sulphuric acid may be looked upon as co bined with lime; what is left, with potash; and, if a *still* remains, with soda.

46. The iodine, and bromine, as combined with magn *sium.*

The chlorine, as united with the remainder of the
sium, and with sodium.

One part of the analysis, may be checked, by
r. Thus, the amount of the fixed constituents,
be equal to the sum of the several ingredients.

QUALITATIVE ANALYSIS OF ORGANIC SUBSTANCES.

substance to be analyzed, should be as pure as
le. The amounts of the organic, and the inorganic
, should be ascertained, by drying it in a water bath
in vacuo, with sulphuric acid—and weighing: then
ng to a high heat, and again weighing. The dif-
e of the weights will indicate the amount of organic
driven off.

Nitrogen.—If, during the ignition, a smell resem-
that of burnt feathers is perceptible, nitrogen is pre-
When the quantity of that element is very small, it
e detected, by putting a bit of potassium at the bot-
a test tube, and placing upon it some of the sub-
s to be examined: then heating to a dark redness,
lamp. The residue—after it has cooled—being dis-
, with four or five drops of distilled water, the solu-
poured off, and added to a liquid, containing mag-
oxide of iron. If any nitrogen is present, a dirty
precipitate—which immedi-
changes to blue, on adding a
hydorchloric acid—is thrown
This test depends on the
hat cyanide of potassium is
l, when an organic substance,
ning very little nitrogen, is
ed at a red heat, with ex-
potassium—atmospheric air
excluded. The experiment
ot, however, be successful, if
bstance, under examination,
dentally mixed with a nitrate,
h an ammoniacal salt.

Sulphur.—To ascertain if
ganic body contains sulphur.
of it is boiled, almost to dry-
ith a strong solution of caus-

FIG. 31.

tic potash; and, the residue being dissolved in water, the solution is poured into a bottle A, fig. 31. The cork B, having the funnel PH fixed in it, is then inserted, but not air-tight, into the neck of A: a slip of paper D, which has been well moistened with a solution of acetate of lead, and then touched with a solution of carbonate of ammonia, having been previously attached to the cork. When hydrochloric acid is introduced, gradually, through the funnel, if sulphur is present, the slip of paper wil ɹturn brown —sulphuretted hydrogen being evolved.

52. *Phosphorus.*—Solid substances are mixed with carbonate of soda, and nitrate of potash: and nitrate of potash, heated to fusion in a porcelain crucible is then thrown into the mixture. The result, when cold, is dissolved in water: and, the solution being acidified with hydrochloric acid, one or two drops of perchloride of iron, and then an excess of acetate of potash, are added. If phosphoric acid is present, in any form or combination whatever, it is thrown down as a white, flocculent, gelatinous, perphosphate of iron ($3PO_5+2Fe_2O_3+3HO$); and the fluid will be colourless, unless too much perchloride has been employed—in which case it will be red.

53. If the organic substance under examination is a fluid, it is treated with a mixture of nitric acid and chlorate of potash—at first without, but afterwards with, application of heat; and, most of the excess of nitric acid being removed, the phosphoric acid is precipitated, as before, with the perchloride of iron, and acetate of potash.

54. *Chlorine.*—A portion of the organic body is ignited, with caustic potash; and, the residue being dissolved, nitrate of silver is added to the solution. Chlorine is precipitated, as chloride of silver [inorg. chem. 333]. Iodine, and bromine, may be detected, at the same time, by methods which will easily suggest themselves, from what we have said of these substances [inorg. chem. 363 and 367].

55. Quantitative Analysis of Organic Substances.—To ascertain the amount of the different elements, driven off by heat, when the substance has been *found not to contain nitrogen*. A known weight of it, having been finely pulverized, is well dried in a water bath —or *in vacuo*, along with sulphuric acid. It is then, in-

ıtely mixed, with perfectly dry, and warm, oxide of per [inorg. chem. 493], and placed in a "combustion e" TW, fig. 32. The latter—which should be very

FIG. 32.

n, and dry—consists of a glass which fuses with diffi- y. The end T, has been drawn out to a fine point, and netically sealed: and the aperture at W, which is per- ly round, has been thickened at the edges with the r-pipe [inorg. chem. 114]. Some pure oxide of cop- is introduced, first: then a mixture of oxide and the stance to be examined: next, rinsings of oxide—used cleaning out the mortar in which the mixture was e, so as to leave none of the substance adhering to it; rwards, pure oxide; and, in the vacant space outside, ece of amianthus, to abstract the moisture generated, prevent its breaking the glass, before it has been ex- ed by heat—also, to keep the particles of oxide from g, by any possibility, projected from the tube, as the approaches them. The arrangement should be com- e, before the oxide is cold. An exceeding good, and ectly dry, perforated cork, is now to be inserted into and the whole is shaken, by gentle taps—so as to free pointed end, from oxide, and leave a channel, all along upper side of the tube, that the gases may pass away, y. The small quantity of moisture that may have absorbed, while the arrangements were being made, moved, by putting the tube into a trough A, fig. 33, aining sand, the temperature of which exceeds 212°, *is not sufficiently* elevated to char paper. The air in

the tube is drawn out a few times, by means of the exhausting syringe Q: and the fresh air, which is admitted

FIG. 33.

from the atmosphere on opening the stop-cock P, is completely dried, by the fused chloride of calcium in the apparatus E.

56. The combustion tube is next placed in the small furnace Z, fig. 32, which is made of sheet iron. It may be about two feet long, four inches high, five inches wide at the top, and three at the bottom. Small slits across the latter, form a species of grating: and upright transverse pieces, riveted to it, support the combustion tube—their upper edges being all of exactly the same height, and coincident with the lower edge of an aperture, in one end of the furnace. The fire is confined to any particular portion of the combustion tube, by movable screens A and B. A similar screen H, protects the cork of the combustion tube, from the fire within the furnace. The air must be allowed to pass freely, during the operation, through the grating. The smaller end of the apparatus F—which contains fused chloride of calcium, and has been previously weighed—is inserted air-tight, in the open end of the tube TW, and is carefully connected, by means of a bit of Indian rubber tubing [inorg. chem. 94] Q, with the caustic potash apparatus D. The latter, consists of a tube bent as represented, and having five bulbs blown upon it—that a large surface of potash may be exposed to the gases which will pass through it. Having been carefully weighed, it is placed on a cloth S, and is raised, at one side, by a cork, &c. *If* the whole apparatus is air-tight—which is quite *indispensable*—a red hot coal, held near the larger side *bulb P, will* cause the air within it to expand, and par

tially escape from the apparatus: after which, on cooling, the solution of caustic potash will ascend towards it. And if, at the end of five minutes, the potash shows no tendency to assume its former position, it may be concluded that every thing is as it should be.

57. A sufficient quantity of red hot charcoal having been placed close at hand, that part of the combustion tube which is next the end T, is enclosed between two screens, and then surrounded with small pieces of lighted charcoal —so as to make it red hot, as soon as possible. One of the screens is then gradually shifted back—about an inch at a time—that new portions of the tube may be exposed to the burning fuel.

58. The aqueous vapour, and the carbonic acid, evolved by the decomposing organic substance, will be absorbed, respectively, by the chloride of calcium, and the caustic potash. The bubbles of gas should be made to pass off uniformly, and not too rapidly:—some of them, at first, will not be absorbed, since they will consist of atmospheric air, driven out of the tube. When the evolution of gas ceases, which generally occurs suddenly, the lower bulbs of the potash apparatus are laid in a horizontal line, by removing the cork, which was placed under one side: and, as soon as the potash is seen rushing towards Q, the fine point of the combustion tube is clipped off, with a pair of scissors. This allows the atmospheric air to enter, and supply the vacuum caused by the cooling. Suction through the potash tube, will make the residual aqueous vapour, and carbonic acid, pass into what is intended to absorb them.

59. After about half an hour, the chloride of calcium tube, and the potash apparatus, are again weighed. The increased weight of the former is due to the water: and that of the latter to the carbonic acid, absorbed. The excess of the sum of the weights of the water and carbonic acid, above the weight of the—previously determined—organic part of the substance analyzed, is due to oxygen derived from the oxide of copper; and must, therefore, be deducted from the oxygen of the result. The amount of water, is the weight of the chloride of calcium tube *after*, minus its *weight before*, combustion. 11·111 per cent. of *this is hydrogen*: and 88·888 oxygen. The weight of the

carbonic acid, is the weight of the potash apparatus *after*, minus its weight *before*, combustion :—27·273 of this is carbon : and 72·727 oxygen. The carbon in the substance, is the carbon of the carbonic acid : its hydrogen, the hydrogen of the water ; and, since it is not supposed to contain nitrogen, phosphorus, &c., its oxygen is the weight of its organic part, minus the sum of the weights of the carbon and hydrogen. The per centages of carbon, hydrogen, and oxygen, may be found, from these.

60. *Nitrogen.*—The quantitative determination of this, is effected by a separate process. And, since the oxide of copper would change a portion of it into nitric oxide—which would be converted, by the potash, into nitrous acid, and retained—the quantity of carbon would appear greater than it really is. Hence, when substances containing nitrogen are analyzed, the oxygen compounds of that element must be decomposed, before they pass out of the combustion tube. This is effected, by laying over the oxide of copper —for about four or five inches of the anterior portion of the tube—pure copper turnings : and keeping them intensely ignited, during the entire process. The nitrogen then passes off uncombined.

61. To estimate the amount of nitrogen. The substance is placed along with the oxide of copper, and clean iron turnings, in the combustion tube, which may, in this case, be sealed, without being drawn to a fine point. Five or six inches of bicarbonate of soda, previously placed at the sealed end of the tube, on being intensely heated, evolve carbonic acid—which expels the atmospheric air, at the commencement, and the nitrogen, at the end of the process : and the gases, that pass from the combustion tube, are transmitted into a mercurial pneumatic trough. All the atmospheric air may be known to have been driven off, when the gas, being transmitted into a test tube, containing potash solution, and inverted over the mercury, is entirely absorbed. As soon as this is the case, a graduated jar—which has been previously filled, two-thirds, with mercury, and the remaining third, with solution of caustic potash—is, by means of a ground glass plate, inverted, and then placed in the mercury, in such a way that the gas from the combustion tube may ascend into it. And, to

complete the separation of the carbonic acid from the nitrogen, the graduated jar should be left at rest, for some time after the process is finished. The jar is then removed to a vessel of water: and the mercury, and potash, having descended through that fluid, the liquid in, and outside, of it is brought to the same level, and the nitrogen is read off. The proper corrections are made for pressure [pneum. 42], temperature [heat 72], and the presence of aqueous vapour [heat 103]. The weight is deduced from the volume.

62. The result will, probably, be found a little too high; on account of its being very difficult to prevent some atmospheric air from remaining attached to the oxide of copper.

63. *Sulphur.*—When the organic substance contains sulphur, some of it, becoming sulphurous acid, will be absorbed by the potash—unless a tube, about six inches long, and filled with perfectly dry peroxide of lead, is interposed between the combustion, and the chloride of calcium tubes, fig. 32. Sulphate of the protoxide of lead is then formed, and detained. $SO_2+PbO_2=SO_3+PbO$.

64. To ascertain the amount of sulphur. The organic substance, having been finely pulverized, is fused in a large silver dish, with twelve times its weight of caustic potash; and then, having been mixed with about half its weight of nitre, it is heated, till the fused mass is quite white. The whole is next supersaturated with hydrochloric acid; and nitrate of barytes is added. The sulphuric acid is estimated, from the resulting sulphate of barytes, in the way we have already described [22]. 40 per cent. of the sulphuric acid is sulphur.

65. *Phosphorus.*—When an organic substance contains phosphorus, its amount is ascertained by oxidizing with a mixture of nitric acid and chlorate of potash. The phosphoric acid is obtained, from the resulting solution: and is estimated in the usual way [24]. 43·915 per cent. of the phosphoric acid is phosphorus.

66. When the organic substance contains chlorine, subchloride of copper will be formed in the combustion tube, and will be condensed in the chloride of calcium tube—unless *chromate of lead* is substituted for the oxide of copper. *For this purpose,* more chromate of lead than will be

sufficient to fill the combustion tube—which may be narrow—is heated in a porcelain dish, until it begins to turn brown: and, being then allowed to cool below 212°, it is substituted for oxide of copper. The other arrangements remain the same—except that the chromate not being hygrometric, the exhausting syringe [55] is not required. Chloride of lead—which remains in the combustion tube—is formed.

67. *Chlorine.*—The amount of this is determined, by igniting the organic substance, in a combustion tube, with a mixture, consisting of three parts hydrate of lime and one part hydrate of soda; then dissolving the ignited mass, in very dilute nitric acid; and precipitating the chlorine, with nitrate of silver. The chlorine is estimated, as before mentioned [26].

Bromine, *Iodine*, &c.—Substances containing these, are treated in the same way; and their weights are determined, as before [25 and 26].

68. Analysis of a Soil.—About one pound of what may be considered a fair average of it; and the same quantity of subsoil, lying immediately beneath, are placed in canvass bags, and labelled. It is to be remembered, that a difference of subsoil will cause a difference in the degree of fertility. The portion of each, which is to be used in qualitative, and quantitative, analyses, having been carefully dried in the air, and well mixed, is placed in a stoppered bottle.

69. *Specific gravity.*—This is determined, by drying some of the soil, at 212°, and introducing it into the specific gravity bottle, half filled with distilled water [hyd. 57].

70. *Sand, gravel.*—About 500 grains are well agitated with hot water, in a large flask; the whole mixture is then poured into a jar, and allowed to stand for a couple of minutes; after which the water and the finer portion of the soil suspended in it, are poured off into another vessel. This is repeated, until nothing but sand and gravel are left behind. The latter is thoroughly dried, and then passed through gauze sieves, of different degrees of fineness. The separated portions are each weighed; then moistened with water, and examined with a microscope—for the purpose of learning the substances, of which they consist. If

moistening them with a few drops of hydrochloric acid, causes effervescence, *limestone* is present; if a brown colour has been imparted to the acid, *peroxide of iron:* and, if there is a smell of chlorine, peroxide of manganese.

The other ingredients, likely to be found, are detected by the appropriate tests.

71. *Absorbent powers.*—500 grains are exposed to the atmosphere, on a sheet of paper, for twelve hours. If the soil is good, their weight will have increased, by from seven to ten grains: if the increase has been fifteen, or twenty grains, it is an excellent indication. The same portion of the soil is to be next placed on a double filter, in a funnel; and water is poured on it, till drops begin to fall from the funnel. It is then covered with a glass, and allowed to stand for a couple of hours—a little water being occasionally added, until it is certain that the entire is wetted thoroughly. The filters are then removed from the funnel, and placed on a cloth, that the drops, which adhere, may be absorbed:—after this, the filter containing the soil is to be placed in one scale, and the other filter, in the other scale. The increase of weight, will indicate how much moisture is retained. It is next to be spread on a plate, and exposed to the air for a certain number of hours. The weight lost, will show the *comparative* rapidity with which it dries—and, by consequence, whether or not there is a necessity, either for drainage, or irrigation. The times, in which water evaporates from sand, clay, and peat, in the same circumstances, are as four, eleven, and seventeen.

72. Organic Constituents of the Soil.—To ascertain the *total amount* of these. About 150 grains are completely dried, at a temperature not higher than between 250° and 300°, and then weighed. They are next ignited, until all blackness disappears; and afterwards, having been moistened with carbonate of ammonia, are dried, again ignited, and weighed. The difference between the two weights, will indicate the amount of organic matter. The result will not, however, be quite accurate; for, certain soils do not lose all their water, except at a temperature which is sufficient to decompose the organic matter:—also, carbonic acid, nitric acid, and ammonia, may have been driven off.

73. When the soil is treated with water, combinations of the fixed alkalies, ammonia, lime, and magnesia, with formic, acetic, humic, crenic, apocrenic, and carbonic acids, are among the substances obtained from it. Alkaline solutions, will then extract compounds which may be precipitated with acids; and which, from whatever soil they may be derived, exhibit a great uniformity of constitution, and very strikingly resemble the last products [256] of animal, and vegetable, decomposition. The crenic, and apocrenic acids, are always found, in the soil, as salts of ammonia, potash, and soda—combined with lime, magnesia, and oxide of iron: and they are insulated, with extreme difficulty.

74. *Humic acid.*—500 grains of the soil are digested, for several hours, at a temperature not exceeding 200°, with a solution of carbonate of soda; and then filtered:—if the filtered liquor is muddy, it is concentrated, and again filtered. The clear liquor being mixed with hydrochloric acid in slight excess, humic acid precipitates, in the form of light brown flakes—which are to be filtered, washed, dried, and weighed.

75. *Humous acid or humine*, &c.—About 500 grains are digested with caustic potash, for some hours, in a porcelain vessel; the alkaline fluid is then diluted with water, and the undissolved portion is washed in a filter. Hydrochloric acid, added to the clear liquor, precipitates all the humous, in the form of humic acid. The difference between its weight and that of the humic acid, obtained in the experiment, with carbonate of soda [74], indicates the amount of humous acid. And the sum of the weights of the humous and humic acid, deducted from the total weight of the organic matter, gives the weight of the organic elements which do not belong to the humic group.

76. *Waxy, and resinous, substances.*—About 2,000 grains are digested, with strong alcohol; the result is filtered, and the clear liquor is precipitated, by diluting the alcoholic solution, with water.

77. *Nitrogen.*—The amount of this may be determined, by the methods we have already described [61, &c.]

78. *Carbonic acid*, &c.—100 grains of the soil are placed in a counterpoised bottle [18], containing hydro-

chloric acid. The weight lost, will indicate the quantity of carbonic acid which has been driven off. The *ammonia*, if considerable in quantity, may be determined as described [40].

79. CONSTITUENTS OF THE SOIL, WHICH ARE SOLUBLE IN WATER.—About 15,000 grains of the dried earth, is covered with water, in a porcelain capsule, and kept boiling for about an hour—being stirred occasionally. The liquid is then strained through a moistened filter; after which, more water is poured on, and the process is repeated, until a drop of what passes through leaves scarcely any residue, when evaporated. If gypsum is present, the washing is tedious. The entire of the solution is now weighed, and divided into four parts—one of which is twice as large as each of the others. We shall call the three smaller A, B, and C; the larger D.

80. *Total amount of soluble ingredients.*—To ascertain this, part A is evaporated, to dryness: then ignited, for some time, in a platinum crucible, and weighed.

81. *Chlorine*, &c.—This is precipitated from part B, by nitrate of silver, nitric acid being previously added: and the chlorine, &c., are deduced from the chloride [25]. When the silver salts have been removed, hydrochloric acid is added to the clear liquor, and then nitrate of barytes. The amount of the *sulphuric acid* may be found from the resulting sulphate of barytes [22], which should be extremely well washed.

82. *Carbonic acid.*—The amount in C is ascertained by evaporating it to a very small quantity: then placing it, along with hydrochloric acid, in the usual apparatus [18].

83. The carbonic acid, in the insoluble carbonates, may be determined, by drying a portion of the soil, from which the aqueous solution [79] has been obtained, on a filter, and mixing it well: then, using some of it, as we have described [18].

84. *Silex.*—Part D is evaporated to dryness, in a water bath, with hydrochloric acid in excess—being kept stirred all the time; and the residue is dried in a sand bath; then digested, *with hydrochloric* acid, a moderate heat being *applied. The silex*—which remains undissolved—is washed

on a filter with hot water; and, after being well dried, is estimated [28].

85. The liquid from which the silex has been separated, is divided into three equal portions:—one of them is used in determining the amounts of potash, and soda, in the way we have mentioned [37]. The phosphoric acid is determined, by means of another [24]; the alumina [31]; lime [32], magnesia [33], and manganese [36], by means of the third.

86. CONSTITUENTS OF THE SOIL, WHICH ARE SOLUBLE IN DILUTE HYDROCHLORIC ACID.—About 250 grains of what has been used [79], for discovering the ingredients soluble in water, is agitated with some water, in a glass flask, so as to form a pasty mass. Heat being then applied, hydrochloric acid, in excess, is gradually added. The mixture, after this, is kept near the boiling point, for about two hours—the flask being frequently shaken; and then being thrown upon a moist filter, is extremely well washed. The resulting clear liquor is evaporated to dryness, with some nitric acid; the residue is dissolved in hydrochloric acid; and the silex is separated, and estimated, as we have described [28]. The hydrochloric solution, from which the silex has been removed, is divided into three equal portions, which we shall call E, F, and H.

87. *Sulphuric acid.*—Part E is used for determining the amount of *sulphuric acid*, in the same way as part B [81].

88. *Alkalies.*—Part F, to determine the alkalies, in the same way as one portion of D [85].

89. *Phosphoric acid*, &c.—Part H is mixed with ammonia, until a precipitate begins to appear; after which, acetic acid is added, and then acetate of soda. Phosphate of alumina, and phosphate of peroxide of iron, are thrown down; and the mixed precipitate will contain the whole of the phosphoric acid. If there is no iron in the liquor, it will be necessary to add perchloride of that metal, until a red colour is produced. The alumina, and oxide of iron, which—as well as the phosphates—would be thrown down, by the ammonia, are kept dissolved by the acetic acid. The mixture is boiled, for some time; and, while the solution is still hot, the phosphates are separated, by filtration.

They are then placed in a porcelain dish, and dissolved in a little hydrochloric acid. Water—rendered alkaline, with ammonia—is next added to the solution; and, afterwards, hydrosulphuret of ammonia in excess. The sulphuret of iron is filtered, washed with water containing hydrosulphuret of ammonia, and dissolved in hydrochloric acid; and, being boiled with nitric acid, its solution is added to the liquid, from which the phosphates of alumina and of iron were obtained—and which contain the lime, &c. The liquid from which the sulphuret of iron has been removed, is concentrated by evaporation; sulphate of magnesia is added, and is carefully stirred:—the resulting crystalline basic phosphate is changed, by ignition, into pyrophosphate of magnesia—which contains 63·367 per cent. phosphoric acid. The iron, alumina, lime, magnesia, and manganese, are obtained in the way already described [28, &c].

90. Constituents of the Soil which are Insoluble in Water, and Dilute Acids.—The residue, after what is soluble in water, and in dilute acids has been removed [79 and 86], having been well dried, and finely pulverized, in an agate mortar, is transferred to a platinum crucible, along with about seven times its weight of concentrated sulphuric acid, and kept gently boiling, under a good chimney, until it is nearly dry. Hydrochloric acid is next added; then water; and, after being heated, the mixture is filtered. The clear liquor is divided into two parts; one is used to determine the phosphoric acid [24], alumina [31], lime [32], magnesia [33], and manganese [36]; and the other, the alkalies [37].

91. Constituents of the Soil which are Insoluble in Water, and Acids.—If the mass, which remained undissolved in concentrated sulphuric acid [90], dissolves entirely, in caustic potash, or carbonate of soda; it is pure silex, and may be estimated as before [28]. If not, being carefully dried, it is divided into two equal parts: and one of them is fused, with four times its weight of well-dried carbonate of potash [inorg. chem. 613]—a small piece of hydrate of potash being placed in a cavity, made in *the middle* of the mixture: the other, with rather *more than the same* quantity of carbonate of barytes. The

mixture containing carbonate of potash or *white* flux, is heated in a platinum crucible, until it fuses into a glass—which is tinted purple if manganese, but red brown if iron is present. While the crucible, and its contents, are still warm, they are placed, along with distilled water, in a porcelain capsule: and, hydrochloric [inorg. chem. 604], with a little nitric acid being added, the mixture is evaporated to dryness. The residue is heated with dilute hydrochloric acid; and, the silex being removed by filtration, is washed, dried, &c. [28]. The various substances, contained in the clear liquor, may be determined as before [86, &c.].

92. The part which is fused with carbonate of barytes, will require an exceedingly high heat. If fusion is produced, the most refractory minerals are then easily operated upon: if not, the process is imperfect. The platinum crucible, containing the barytic mixture, is introduced into a fire-proof crucible filled with magnesia, and is left in the furnace for a quarter of an hour. The result is treated in the same way, as that obtained by fusion with carbonate of potash [91].

When a mineral, &c., contains double or triple silicates of alumina, it is so refractory, that fusion with carbonate of potash, or barytes, is indispensable.

93. The phosphoric acid, obtained in the examination of a soil, though found in combination with alumina, and iron, may, in reality, have been united, at least in part, with lime, and magnesia. The alumina and peroxide of iron being uncombined, until hydrochloric set the phosphoric acid free, by decomposing the phosphates of lime and magnesia.

94. *Manganese.*—This is generally found in soils, in such small quantities, that it is not necessary to separate it from the iron. It causes the latter, when exposed to the air, to assume a black colour.

95. *Fluorine.*—When, in an analysis, it is desirable to ascertain the amount of fluorine, if the fluoride is soluble, it may be determined, by rendering the solution alkaline, *with ammonia*, and afterwards adding chloride of calcium. The resulting gelatinous fluoride of calcium must be washed on a filter, with hot water, and then with acetic

acid—to remove any carbonate of lime, which may have been produced during filtration. It contains 48·53 per cent. fluorine.

96. When the fluoride is insoluble, it is finely pulverized, and intimately mixed with silex—unless it contains that substance; then placed in a small flask, and weighed: after which, sulphuric acid, that has been concentrated by boiling, is poured over it, and the flask is rapidly closed with a cork, in which has been inserted a tube that contains fused chloride of calcium in fragments, and has been drawn out to a fine point. The whole having been then weighed, the fluoride of silicon is driven off by heat, and the last portion is removed, by the exhausting syringe [55]. The weight lost is that of fluoride of silicon—which contained 72·6 per cent. fluorine.

97. The analysis of the ashes of plants, is a very important subject; and will be greatly facilitated by careful attention to what we have said regarding the analysis of soils, &c.

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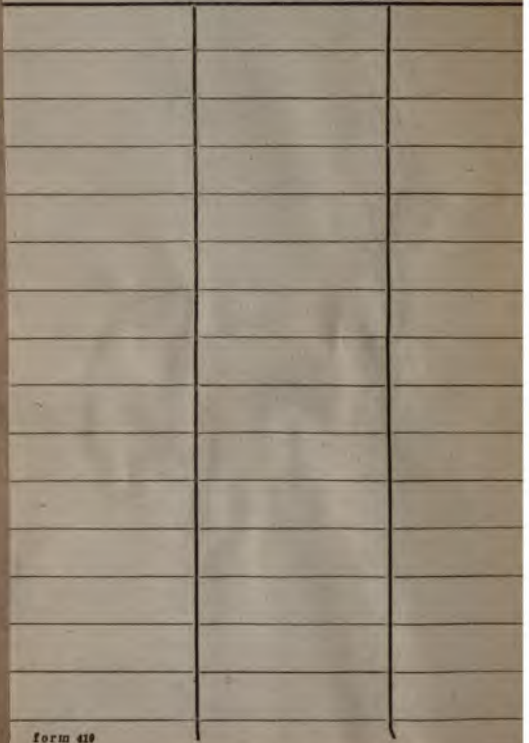

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